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**PALYNOLOGICAL STUDIES
OF THE PALEOGENE AND NEOGENE DEPOSITS
FROM THE POMERANIAN LAKELAND AREA
(NW POLAND)**



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Barbara SŁODKOWSKA — **Palynological studies of the Paleogene and Neogene deposits from the Pomeranian Lakeland area (NW Poland).** *Polish Geological Institute Special Papers*, 14: 1–116

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Abstract:

Part I. Detailed phytoplankton investigations were performed on the Paleogene deposits from the Pomeranian Lakeland. Phytoplankton assemblages were identified and described in 11 boreholes. 136 phytoplankton taxa have been identified. The taxa belong to the classes Dinoflagellata, Prasinophyta, Chlorophyta and to the Acritarcha group. On the basis of taxa composition ecological groups of phytoplankton were defined. A special attention was paid to the role of phytoplankton as an indicator of bathymetry, distance from land, dynamics of water, its temperature, salinity and sea-level changes. Biostratigraphic datings have been based primarily on marine phytoplankton, to a lesser extent on sporomorphs. The Middle Paleocene (Selandian) phytoplankton assemblage (part D3 and D4) has been first described from Poland. Phytoplankton assemblages from Upper Eocene through Upper Oligocene deposits were also identified and dated. The palynofacies analysis of organic and inorganic debris from palynological matter was investigated, augmenting data obtained from the palynomorph analysis. All organic components of palynological matter — both palynomorphs and palynoclasts — were analysed. These data allow to draw palaeoenvironmental conclusions and identify relationships between factors influencing vegetation of plants and depositional processes. All the palynological matter identified in the Middle Paleocene deposits indicate the occurrence of deeper shelf facies. Palynological debris in the Upper Eocene deposits show the sedimentation took place in a fairly deep-water basin, not far from the land. The assemblages, identified in Eocene/Oligocene transition sediments, indicate the deposition occurred in a shallow-marine basin, far from the land, in a moderate-energy environment. Lower Oligocene palynological matter point the a high-energy marine environment and decreasing distance from the coast. Upper Oligocene assemblage provides evidence for a considerable shallowing of the basin and low-energy environment. The marine sedimentary cycle was followed by Miocene continental deposition, as evidenced from the upper part of the section.

Part II. The analyses of the Paleogene and Neogene deposits of the Pomeranian Lakeland resulted in a detailed characteristic of the sporomorph and pollen assemblages derived from 12 borehole profiles. 343 sporomorph taxa related to Recent botanical equivalents have been identified. Similar pollen spectra have been joined into groups, on the basis of which were established the phases of the dominant plant communities (A–K). The defined phases of the dominant plant communities within the model profiles of Komorza 1/KB and Łosiny 2/KB have been correlated with the phases of the plant communities present in the other profiles and attributed to the relevant local palynostratigraphical rank. The recognized spore and pollen assemblages from Lignite Seams II, IIA, I and IA as well as those from the inter-coal deposits were related to the Recent palynostratigraphical, lithostratigraphical and chronostratigraphical subdivisions of Neogene. Reconstruction of the succession of the terrestrial plant communities has confirmed the changes of the palaeoenvironmental conditions. Investigation of the difference between the proportions of the Arctotertiary and Palaeotropical geoflora elements has proved the climatic changes during the formation of the studied sequences. The lower part of the Paleogene section, showed the prevalence of subtropical plant communities with mixed mesophilous forest as well as the abundance of evergreen plants has been noticed. The humid and warm climate has favoured the development of swamps and shrubs forming a coal-producing biomass. In the upper part of the Neogene profile, peatbogs were formed and riparian forest communities and mixed forests, with a smaller share of highly warmth-loving evergreen plants. The element of the Palaeotropical geoflora within the Neogene plant communities became poorer in components due to the distinct cooling of the climate. This element dominated for the last time during the formation of the II Łużyce Lignite Seam. The most important element of the mixed and riparian forests in the upper part of the Middle Miocene was formed by the Arctotertiary geoflora typical of a temperate climate.

Key words: palynology, phytoplankton, palynofacies analysis, pollen analysis, plant communities, biostratigraphy, Paleogene, Neogene, Pomeranian Lakeland.

Abstrakt:

Część I. W osadach paleogeńskich z Pojezierza Pomorskiego przeprowadzono szczegółowe badania fitoplanktonu z 11 otworów wiertniczych. Wyróżniono 136 taksonów fitoplanktonu należących do gromad Dinoflagellata, Prasinophyta, Chlorophyta i grupy Acritarcha. Na podstawie składu gatunkowego zdefiniowano grupy ekologiczne fitoplanktonu. Zwrócono uwagę na jego rolę jako wskaźnika głębokości zbiornika, odległości od brzegu, dynamiki wód, ich temperatury i zasolenia, a także eustatycznych ruchów poziomu morza. Datowania biostratygraficzne oparte zostały przede wszystkim na fitoplanktonie morskim, w mniejszym stopniu na sporomorfach. Po raz pierwszy z obszaru Polski opisany został paleoceński zespół fitoplanktonu, zaliczony do zelandu (D3–D4). Ponadto datowano zespoły fitoplanktonowe z osadów od eocenu górnego do oligocenu górnego (D12–D15). Metodą analizy palinofacjalnej badano wszystkie szczątki organiczne i nieorganiczne zawarte w maceracie palinologicznym, uzupełniając w ten sposób dane uzyskane z analizy palinomorf. Wśród elementów organicznych brano pod uwagę wszystkie składniki materii palinologicznej — palinomorfy i palinoklasty. Przeprowadzono analizę palinofacji w ujęciu środowiskowym na tle syntetycznego profilu osadów paleogenu z obszaru Pojezierza Pomorskiego. Przedstawiono zależność ilościową i jakościową materii palinologicznej od środowiska sedymentacji w facjach od pełnomorskich do lądowych. Materia palinologiczna występująca w osadach środkowego paleocenu wskazuje na panowanie facji głębszego szelfu. Szczątki organiczne w osadach górnego eocenu świadczą, że sedymentacja miała miejsce w dość głębokim basenie morskim, niezbyt daleko od brzegu. Zespół z osadów eocen/oligocen akumulowany był w basenie płytkomorskim w strefie bardziej odległej od brzegu. Szczątki zawarte w osadach oligocenu dolnego wskazują na wysoko-energetyczne środowisko morskie i niewielką odległość od brzegu. Zespół górnooligocenijski rejestruje spływanie basenu i spadek energii wody. Powyżej, w profilu osadów miocenijskich, panują warunki kontynentalne.

Część II. Badania osadów paleogenu i neogenu Pojezierza Pomorskiego pozwoliły na szczegółową charakterystykę zespołów spor i ziarn pyłku z dwunastu profili otworów wiertniczych. Wyróżniono 343 taksony sporomorf i powiązano ze współczesnymi odpowiednikami botanicznymi. Zbliżone spektra pyłkowe zestawiono w grupy, na podstawie których wyznaczono fazy dominujących zbiorowisk roślinnych (A–K). Zdefiniowane fazy dominujących zbiorowisk roślinnych we wzorcowych profilach Komorza 1/KB i Łosiny 2/KB skorelowano z fazami zbiorowisk w pozostałych profilach. Fazom dominujących zbiorowisk roślinnych przypisano lokalną rangę palinostratygraficzną. Opisane zespoły spor i ziarn pyłku z II, IIA, I i IA pokładów węgla brunatnego oraz z osadów międzywęglowych powiązano z aktualnymi podziałami palinostratygraficznymi, litostratygraficznymi i chronostratygraficznymi neogenu. Odtworzono także następstwo zbiorowisk roślin lądowych, co pozwoliło na rekonstrukcję zmian warunków paleośrodowiskowych. Prześledzenie zmian proporcji pomiędzy elementami geoflory paleotropikalnej i arktycznotrzeciorzędowej dało możliwość stwierdzenia wahań klimatu w czasie tworzenia się badanych osadów. W niższej, paleogeńskiej części profilu osadów zapisane jest panowanie zbiorowisk roślinnych klimatu subtropikalnego, z dominacją mezofilnych lasów mieszanych i obfitym udziałem roślin wiecznie zielonych. Wilgotny i ciepły klimat sprzyjał rozwojowi lasów bagiennych i krzewiastych zarośli, tworzących biomasę węglotwórczą. W wyższej, neogeńskiej części profilu, tworzyły się torfowiska oraz zbiorowiska lasów lęgowych i mieszanych z malejącym udziałem wysoce ciepłolubnych roślin wiecznie zielonych. Element geoflory paleotropikalnej w zbiorowiskach roślinnych neogenu, na skutek wyraźnego ochładzania klimatu, stawał się uboższy w składniki i po raz ostatni dominował w czasie tworzenia się węgla II łużyckiej grupy pokładów. W wyższej części środkowego miocenu trzon roślinności lasów mieszanych i lęgowych stanowił element geoflory arktycznotrzeciorzędowej, typowy dla klimatu umiarkowanego.

Key words: palinologia, fitoplankton, analiza palinofacjalna, analiza pyłkowa, zbiorowiska roślinne, biostratygrafia, paleogen, neogen, Pojezierze Pomorskie.

INTRODUCTION

Palynological investigations were performed on the Paleogene and Neogene deposits from the Pomeranian Lakeland (NW Poland). The study area is located in the eastern part of the Pomeranian Lakeland. Samples for palynological investigations were collected from boreholes concentrated in the Brda River valley, north of Koronowo Lake (Fig. 1).

The research material comes from documentation boreholes drilled for lignite deposits in the Kowalskie Błoto and Kłodawa re-

gions (Kasiński, 1987). Two marker sections from the Łosiny 2/KB and Komorza 1/KB boreholes were selected for detailed palynological investigations (Ślodka, 1998b, 2000a, b). Data from these boreholes were augmented with information obtained from ten less densely sampled sections (Fig. 2). Results of own author's investigations was supplemented with results of archival works other authors (Mamczar, 1963; Rębas, 1984; Grabowska, 1985; Grabowska, Ślodka, 1986; Ważyńska, 1987a, b; Ślodka, 1989).

Palynological study was leaning on two different palynomorph groups. From this reason the work composition is divided on two parts. First embraces results of phytoplankton analysis of the Paleogene deposits together with palynofacies analysis. The pollen analysis was used for palynological studies of the Paleogene deposits. It was additionally supplemented with the phytoplankton analysis. Since the seventies, such methods have been employed to study Paleogene and Neogene deposits from the Pomeranian Lakeland. Phytoplankton assemblages, characteristic of the Lower Oligocene, were identified in the regions of Toruń (Grabowska, 1970b, 1973), Nakło upon Noteć (Grabowska, 1974; Ważyńska, 1977), Bydgoszcz (Grabowska, 1970b, 1973) and Chełmno (Grabowska, 1967, 1970a). The boreholes Łyskowo PG 1 (Rębas, 1984), Wilcze IG 1 (Grabowska, 1985), Kłodawa 4/Kł and Kłodawa 5/Kł (Ważyńska, 1987a, b) were drilled in the area studied in details by the present author. The Paleogene deposits encountered in these boreholes are dated at the Upper Eocene and Lower Oligocene. The present author also analysed Paleogene and Neogene sections from the boreholes Kamień 2/KA (Grabowska, Słodkowska, 1986) as well as Raciąż II, Obrowo III, Jeleńcz IV, Tuchola-Białowieża VI, Mędromierz V, Piła Młyn V, Wymysłowo XI, Gostycyn IV and Lisie Jamy X (Słodkowska, 1989).

Second part of this paper contains results of pollen analysis Paleogene and Neogene deposits. First spore-pollen study lignite deposits from the Pomeranian Lakeland was elaborated from Krostkowo near Noteć river (Rejman, 1955; Jakubowska, 1956, 1957). These deposits as Pliocene was dated in that time. Since the sixties Myśligoszcz 1, Gronowo 2 and Gronowo 3 was described (Mamczar, 1963). Near investigation area well known are single profiles elaborations Inowrocław (Jakubowska, 1958), Ciechocinek (Mamczar, 1960) and Chełmno (Grabowska, 1967). Then palynological research of the 'Tertiary' deposits near Toruń (Grabowska, 1970b, 1973), Nakło near Noteć river (Grabowska, 1974; Ważyńska, 1977; Kohlman-Adamska, 1993), Bydgoszcz (Kościelniak, Wanat, 1974; Grabowska, 1970, 1973), Chełmna (Grabowska, 1970a) and Świecie (Domagała, Matl, 1977). From the study area was profiles: Łyskowo PG 1 (Rębas, 1984) i Wilcze IG 1 (Grabowska, 1985) and study by the present

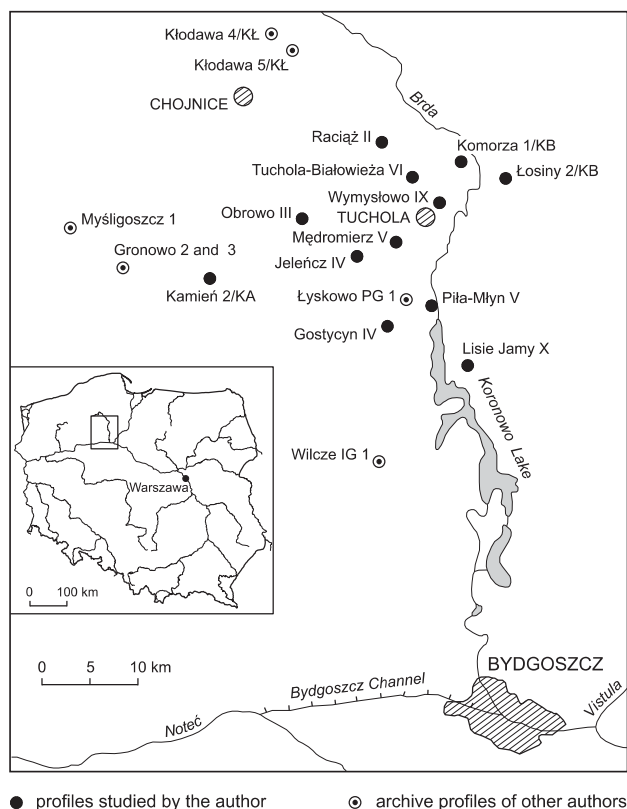


Fig. 1. Location map of the studied sites

author profiles: Kamień 2/KA (Grabowska, Słodkowska, 1986), Raciąż II, Obrowo III, Jeleńcz IV, Tuchola-Białowieża VI, Mędromierz V, Piła Młyn V, Wymysłowo XI, Gostycyn IV, Lisie Jamy X (Słodkowska, 1989, 1992, 1994), which supplemented main profiles Łosiny 2/KB and Komorza 1/KB (Słodkowska, 1998b).

The main purpose of the studies was to establish palynostratigraphy of investigated deposits, reconstruct sedimentary conditions, identify palaeogeographic changes as well as plant communities reconstruction across the area in that time.

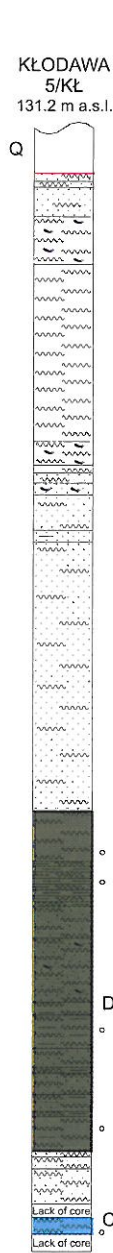
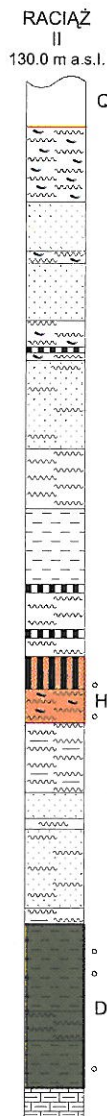
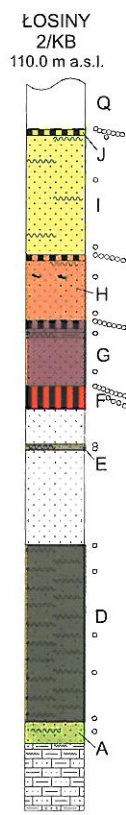
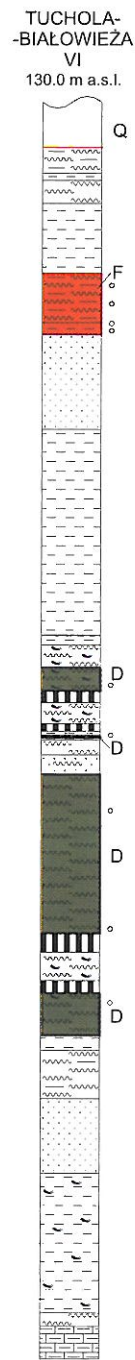
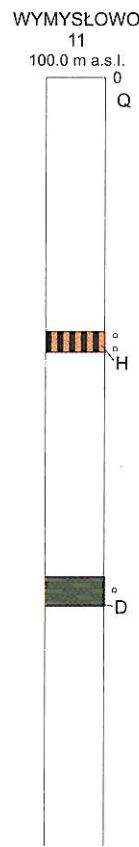
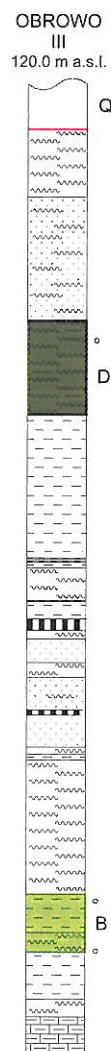
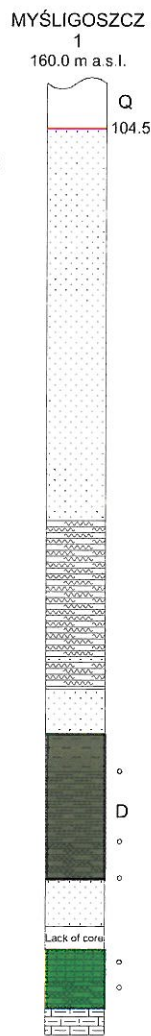
GENERAL OVERVIEW OF THE GEOLOGICAL STRUCTURE OF THE POMERANIAN LAKELAND

The palynological investigations were performed in the area of the Pomeranian Lakeland located within the two tectonic units: Marginal Trough and Mid-Polish Swell (Znosko, 1998). Northern part of the area is situated within the Pomeranian Trough, whereas southern part — within the Pomeranian-Kujawy Swell. The northern part belongs to the Tuchola tectonic-structural unit of the Pomeranian Trough. The southern part covers the area of the Więcbork tectonic-structural unit extending within the Pomeranian-Kujawy Swell (Dadlez, 1980; Marek, 1997; Marek, Pajchłowa, 1997). The Marginal Trough and Mid-Polish Swell were part of the Mesozoic Mid-Polish Trough (Dadlez, 1997). It is more justifiable to use

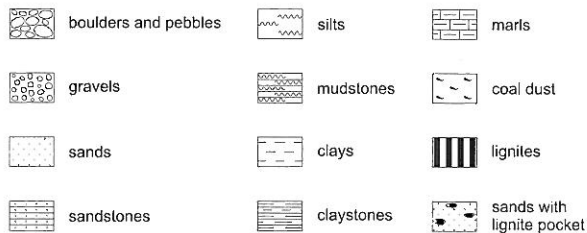
the term Mid-Polish Trough for this area which lies within both the Tuchola and Więcbork units.

In the sixties and seventies, a number of deep boreholes were drilled on the Tuchola and Więcbork tectonic-structural units (e.g. Babilon 1, Bysław 2, Charzykowy IG 1, Chojnice 2, 3, 4, 5, Człuchów IG 1, Debrzno IG 1, Kłosnowo IG 1, Lutom 1, Nicponie 1, Raciąż 1, Stobno 1, 2, 3, Tuchola IG 1, Wilcze IG 1). These boreholes have yielded much research material for various analyses, including palynological investigations (Grabowska, 1985; Waksmundzka, 1992). Results of those studies have much contributed to the exploration of the geological structure of this part of the Polish Lowlands.

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LITHOLOGY



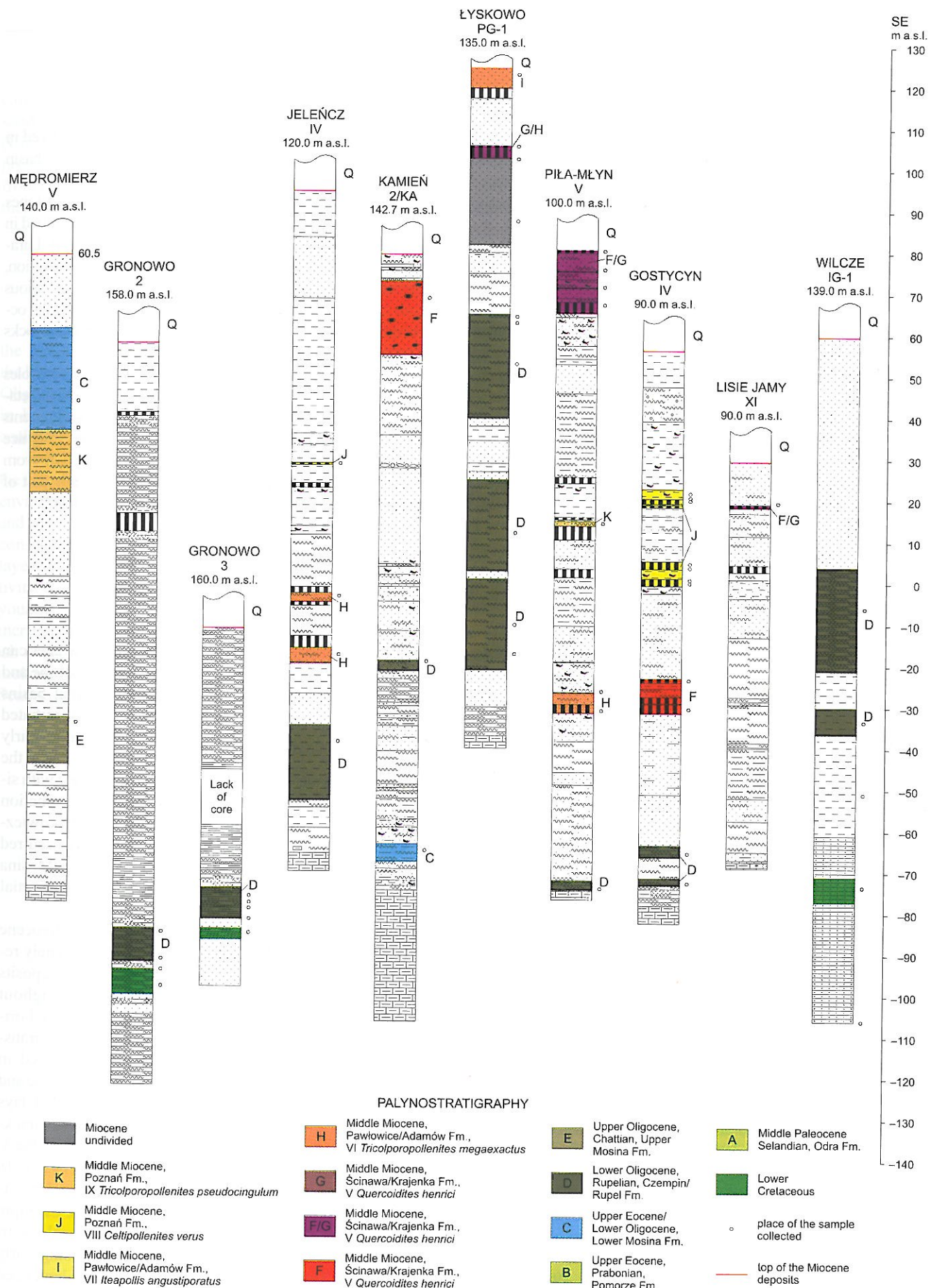


Fig. 2. Palynological profiles in the Tuchola region

SUB-CENOZOIC BASEMENT

Mesozoic rocks are represented in this area mostly by marine deposits which show syndimentary tectonics, resulting from periodically high and variable subsidence within the basin. Since mid-Late Cretaceous times the axial part of the Mid-Polish Trough started to be uplifted due to tectonic movements. In the Maastrichtian and at the Maastrichtian/Danian transition the Mid-Polish Trough was inverted to form the Mid-Polish Swell. Due to tectonic stresses and a local increase in subsidence rate close to the edge of the rigid Precambrian Platform, salt movements became more intense and salt and non-salt anticlines were ultimately shaped at that time.

A remnant sea persisted in the Pomeranian Trough in the Paleocene. Salt diapirs, known from the region located south-west of the study area, had formed before the Middle Eocene (Raczyńska, 1987a, b; Marek, Pajchłowa, 1997). Erosion, that affected the area after the Maastrichtian and before Oligocene transgression, reached locally in the south-western area as deep as the Jurassic deposits.

Uppermost Cretaceous (Maastrichtian) deposits, preserved in the Pomeranian Trough, indicate a regressive trend of the basin evolution. A basin shrinking and influx of terrigenous material resulted in deposition of sandstones, marls, marly-sandy limestones and gaizes (Krassowska, 1997). The regressive trend continued in the Early Paleocene — Danian. However, due to the early Laramide uplifting movements at the Maastrichtian/Danian transition, sedimentation rate decreased. Sedimentary gaps, spanning various intervals of the succession, are presumably associated with the occurrence of hardground or deeper erosion of earlier-deposited rocks (Jaskowiak-Schoeneichowa, 1987; Krassowska, 1997).

Cretaceous deposits have been encountered in all the boreholes that drilled through the Cenozoic complex in this area. The Cretaceous/Paleogene transition period abounded in global-scale events of cosmic disaster. Fall of the Kłodawa meteorite near Chojnice took place at that time, as evidenced from data derived from the Kłodawa 5/Kł borehole. This meteorite was probably part of a larger Kościerzyna impact structure (Kasiński *et al.*, 1987).

CENOZOIC

PALEOGENE

Paleogene deposits are included within the younger complex of the sedimentary cover and belong to the epicontinental structural unit which is a fragment of the North German-Polish Basin. The Paleogene section is dominated by shallow-marine and brackish sediments deposited in several marine transgressive-regressive cycles. The seas most frequently transgressed from the North Sea area (Ciuk, Piwocki, 1990).

The first 'Tertiary' lithostratigraphic schemes for the Polish Lowlands were proposed by Ciuk (1967, 1970, 1974), and for the south-western part of the Polish Lowlands — by Dyjor (1968, 1969). The schemes were subsequently modified by Dyjor (1970, 1986) and Piwocki (Piwocki, Ziemińska-Tworzydło, 1995, 1997; Piwocki, Olszewska, 1996; Piwocki, 1998, 2001).

In the Pomeranian Trough marine sedimentation continued in the Paleocene (Piwocki, Olszewska, 1996; Piwocki *et al.*, 1996). Maastrichtian deposits are locally overlain by Danian sediments (Puławy Formation), however no continuous succession from the Maastrichtian/Danian transition has been found so far. At Pamiętowo near Chojnice, the Early Paleocene — Danian (Montian) foraminiferal fauna (Pożaryska, 1967; Pożaryska, Szczuchura, 1968) has been identified in the Puławy Formation limestones and marls which overlie a Lower Maastrichtian hardground. The sea, existing in this area at the end of Paleocene (late Laramide phase), retreated towards the north-west during the Danian. Only one site of Paleocene deposits, located near Szczecin (Odra Formation — Goleniów IG 2), has been known up to now (Grabowska, 1983).

At the latest Paleocene and in the Early Eocene, denudation and erosional processes dominated over the study area

(Piwocki *et al.*, 1996). Therefore, no deposits of these ages can be found here. Locally, in the Szczecin Trough, lacustrine and swamp deposits accumulated in isolated continental basins (Grabowska, 1983). Another transgressive cycle was initiated due to the Late Lutetian descending trends at the latest Early Eocene and in the Middle Eocene. The cycle culminated in the Late Eocene. The sea transgressed from the north-west with simultaneous inundation from the east, resulting in the formation of one vast basin of the Polish Lowlands (Piwocki, Olkiewicz-Paprocka, 1987). Pyrenean epeirogenic movements occurred at the Late Eocene/Early Oligocene transition (Lower Mosina Formation) causing an uplift of the Polish Lowlands and partial retreat of the sea (Ciuk, Piwocki, 1990).

The next transgression took place in the Early Oligocene and continued through Oligocene time. The sea ultimately retreated at the latest Oligocene. The Lower Oligocene deposits (Czempin/Rupel Formation) are widespread throughout the Polish Lowlands. They form an important correlation horizon. Both vertical and lateral facies variations, caused by transgression/regression oscillations, are commonly observed in these deposits (Ciuk, Piwocki, 1990). The Rupelian marine and brackish deposits correspond to the so-called Septarian Clays of Germany and are most frequently synchronous with brackish-lacustrine sediments containing lignite interbeds of the V Czempin Lignite Seam (Grabowska, Piwocki, 1975). In the north-western part of the Polish Lowlands these deposits are called the Toruń Clays. They included within the Czempin Formation, were deposited in lacustrine and lagoonal basins within a tidal zone at the forefield of the transgressing Early Oligocene sea. They are composed of grey-brown laminated siltstones. The basin coastline cannot be precisely defined due to facies interfingering (Grabowska, Piwocki, 1975).

At the latest Rupelian, downward epeirogenic movements caused that the sea transgressed onto the area depositing quartz sands and glauconite sands of the Upper Mosina Formation (Ciuk, Piwocki, 1990). Upper Oligocene deposits have been preserved only fragmentarily. The sea had ultimately retreated from the northern part of the Polish Lowlands at that time, and then denudation processes on land reigned over the area.

NEOGENE

A complete change in sedimentary conditions took place in the Neogene and continental deposition became dominant in the Polish Lowlands. In the Miocene, after the retreat of the Late Oligocene sea, coal-prone swamp plant communities developed in boggy areas under specific climatic conditions. Several coal-forming cycles are observed in the Miocene succession.

From beginning of the Middle Miocene sedimentation of the terrestrial deposits was developed in the river, lake and swamp environments. On the Pomeranian Lakeland area in the humid and warm climatic conditions, extensive swamps dominated. As consequence of the intensive subsidence origin thick of lignite layers of II Łużyce Seam. At the Middle Miocene tectonic activity clearly appeared. Part of Mesozoic structures became younger. Thickness of the Neogene sediments in trough fault increased. Inland sedimentary basin covered considerable Polish Lowlands area. Fine-grained quartz sands was then accumulated (Adamów Formation) with lignite lenses of IIA Lubin Seams. In warm, humid climate took place progressed marsh

up of considerable Lowland area and luxuriant development of peat vegetation. These factors led to create I Middle Polish Lignite Seam, which determining correlation level the greatest stretches on the Lowlands. In upper part of the Middle Miocene cooling and aridity of the climate took place. It stopped development of swamp sedimentation. Clay sediments origin in this time, lignite of IA Oczkowice Seam was formed only locally. Clay and silt sedimentation of Poznań Formation to go on permanent to Early Pliocene in inland basin (Dyjur, 1968, 1970, 1992; Różycki, 1972; Dyjur, Sadowska, 1977).

QUATERNARY

Pleistocene ice-sheets invaded onto a diverse Neogene topography, resulting in the formation of many erosional and accumulation forms. Recently, Neogene deposits from the Tuchola region are overlain by 10–170 m-thick Pleistocene sediments filling deep glacial troughs incised in Miocene deposits. The Neogene deposits are deformed and folded e.g. near Tuchola, Gostycyn, Piła-Młyn (Butrymowicz, 1978). Glacio-tectonic deformations, observed within Neogene deposits, are associated with the occurrence of deep-seated tectonic structures of the basement (Łyczewska, 1964).

Abundant dunes and thin covers of river valley deposits were formed during the Holocene. These are fluvial sands and gravels of the Brda River valley, and silts, peats and lacustrine chalk deposited within small topographic lows e.g. around Okierskie Lake (Kasiński, Budzyk, 1990).

PART I

PHYTOPLANKTON STUDIES AND PALYNOFACIES ANALYSIS OF PALEOGENE DEPOSITS

RESEARCH METHODS

METHODS OF THE SAMPLES PREPARATION

Samples for palynological analyses were macerated in the Palaeobotany Laboratory of the Polish Geological Institute. Laboratory treatment involved crumbling of rocks and collecting ca 5 g of sediment from inside of each sample. Carbonates were removed using 10% HCl. The material was subsequently boiled in 7% KOH in order to eliminate humic compounds. Mineral fraction was isolated from organic matter by means of dense-media separation and with a use of cadmium iodide and potassium iodide of density 2.2 g/cm³. Organic matter was macerated using the modified Erdtman (1954) acetolysis method. 20 × 20 mm glycerine preparations for microscopic studies were made out of the obtained macerate. The preparations were analysed using the „Leica” ARISTOPLAN biological microscope at magnification of 400× and 1000×. Photographs were taken in the transmitted light using a 40×/0.75 objective.

After standard laboratory preparation methods was received palynological matter which contain apart from palynomorphs, the preparations also contained organic and inorganic debris. Phytoplankton was identified according to the morphological taxonomy (e.g. Grabowska, 1996; Fensome *et al.*, 1993; Williams *et al.*, 1993; Köthe, 1990; Heilmann-Clausen, 1985). In the samples frequency and state of preservation of phytoplankton were generally good.

Biostratigraphic conclusions are based on taxonomically diverse marine phytoplankton, abundant in the Paleogene deposits. Phytoplankton is also an important indicator of the sedimentary environment. Samples with high frequency of phytoplankton usually contained fewer sporomorphs, useless for stratigraphical considerations. The detailed analysis of phytoplankton assemblages has allowed to establish the biostratigraphy of the Paleogene deposits. In order to document these results, tables of phytoplankton occurrence in the Paleogene deposits have been constructed. Individual species are listed in a stratigraphical order with regard to the last occurrence of the taxon in the section. Stratigraphical positions of phytoplankton assemblages are referred to the Paleogene litho-stratigraphic scheme proposed for the Paleogene by Piwocki *et al.* (1996) and Piwocki (2001).

The photographic plates illustrate the following: — Paleocene phytoplankton assemblages first described from Poland (Pls. I–V); — phytoplankton assemblages typical of the Lower Oligocene (Pls. VI–XI); — palynological matter variability as an example of various palynofacies (Pls. XII–XIV).

The table of phytoplankton occurrence (Appendix A) includes names of taxa (genus and species) and names of creators. The latter were ignored in the text, diagrams and graphs.

METHODS USED IN PHYTOPLANKTON STUDIES

Phytoplankton studies of the Paleogene deposits involve the analysis of cysts of unicellular algae belonging to the division Dinoflagellata, Prasinophyta, Chlorophyta, and morphological (polyphyletic) Acritarcha group. Dinoflagellate cysts have a particular importance for biostratigraphic purposes. In "Tertiary" times it was a very progressive group which generated many species rapidly evolving and occurring en masse in relatively short time. These short-living species are characteristic of individual time intervals of the Paleogene. Apart from typical species, there are also long-living dinoflagellate species which, together with some representatives of Chlorophyta (including freshwater plankton) and Acritarchs, are good palaeoenvironmental indicators.

Stratigraphical conclusions have been drawn on the basis of taxa whose nomenclature is based on cysts morphology. Fensome *et al.* (1993) and Williams *et al.* (1993) created foundations of modern taxonomy and biostratigraphy of Dinoflagellata. The international stratigraphic scheme, basing on the dinoflagellate biozonation established from materials originating from north-western Europe, was published by Costa and Manum (1988). Powell (1992), assuming the time scale of Haq *et al.* (1987), modernized and supplemented the scheme with data from other publications, and correlated it with biostratigraphic schemes which were based on other microfossil groups. Fundamental papers for biostratigraphic-palaeoenvironmental considerations are those by Köthe, (1990) and Brinkhuis (1994), who underline the role of dinoflagellate cysts as palaeoenvironmental indicators providing information on salinity, temperature, bathymetry, distance from the land and eustatic sea-level changes.

Another method used by the author was the palynofacies analysis understood as identification of all organic debris from the analysed material (Manum, Thronsdén, 1978; Manum, 1983; Baltes, 1984; Van Bergen *et al.*, 1990; Mussard *et al.*, 1994; Sitter, Ollivier-Pierre, 1994; Tyson, 1995; Batten, 1996, 1999), supplemented with identifications of inorganic components.

The palynological analysis relies on the isolation of vessel plants and palynomorphs from residuum obtained due to maceration. Components extracted from the residuum are represented mostly by wood fragments with preserved tissue structures, e.g. tracheids, conducting vascular tissues, cuticles and stomata. Amorphous organic matter of various colours from opaque through

yellow to brown is also observed. These are, among others, resin and wax, and black amorphous carbonaceous fragments of various shapes and sizes. Animal organic debris is represented mainly by foraminiferal linings. Inorganic matter includes glauconite grains, sponge spicules and occasional gypsum crystals.

All the components augment information obtained from the palynomorph analysis, and enable full reconstruction of the sedimentary environment and thermal maturity of investigated deposits. They also facilitate stratigraphical correlations in case of lack of any other indicators (Manum, 1983; Van Bergen *et al.*, 1990; Mussard *et al.*, 1994).

RESULTS OF PHYTOPLANKTON ANALYSIS

Results of the phytoplankton analysis are based on data from the two densely sampled sections of the Komorza 1/KB (Fig. 3) and Łosiny 2/KB (Fig. 4) boreholes, supplemented with data from nine less densely sampled boreholes. Furthermore, the author's own results (Table 1) are augmented with information from available archival elaborates of other authors (Table 2).

KOMORZA 1/KB

Two phytoplankton assemblages have been identified within over an 80 m-thick series of Paleogene deposits (Fig. 3). The oldest one comes from a depth of 203.20–248.50 m from sandy silts, glauconite sandstones and marly limestones. Among palynomorphs, there is an abundance of phytoplankton with little amount or absence of pollen grains.

Marine phytoplankton, represented largely by dinoflagellate cysts, was abundant and diverse. The following specimens have been identified, among others: *Alterbidinium circulum*, *Apectodinium*, *A. summisum*, *Apteodinium*, *Areoligera coronata*, *A. senonensis*, *Caligodinium aceras*, *Cerodinium* cf. *dartmoorium*, *C. diebelii*, *C. medcalfii*, *C. striatum*, *Cleistosphaeridium insolitum*, *Cordosphaeridium fibrospinosum*, *Diphyes colligerum*, *Distatodinium* cf. *ellipticum*, *Fibradinium*, *Fromea*, *Hystrichokolpoma cinctum*, *Hystrichosphaeridium tubiferum*, *Isabelidinium* ? cf. *vibrogense*, *Kallosphaeridium*, *Membranosphaera*, *Microdinium* cf. *ornatum*, *Palaeocystodinium australinum*, *P. denticulatum*, *Palaeoperidinium pyrophorum*, *Palambages morulosa*, *Palaeotetradinium minusculum*, *Phthanoperidinium cernulatum*, *Spinidinium clavum*, *S. densispinatum*, *S. echinoideum*, *Spiniferites ramosus*, (Pls. I–V, Fig. 3). There are also individual, poorly preserved and corroded pollen grains. Microscopic preparations also contained foraminiferal linings and individual glauconite grains indicating the marine sedimentary environment.

At that depth interval, the phytoplankton assemblage composition shows features typical of assemblages from the Middle Paleocene — Selandian deposits developed as the Odra Formation.

The second assemblage has been identified within the overlying sandy silts at a depth of 167.21–198.25 m. The funda-

mental difference, if compared with the previous assemblage, is high frequency of spores and pollen grains and less contribution and diversity of marine phytoplankton represented by, among others: *Chiropteridium lobospinosum*, *Wetzeliiella articulata*, *W. meckelfeldensis*, *W. symmetrica*, *Palaeocystodinium golzowense*, *Deflandrea phosphoritica*, *Membranophoridium aspinatum*, *Hystrichokolpoma rigaudiae*, *Rhombodinium freienwaldense*, *Rh. pustulosum*, *Rh. logimanum*, *Glaphyrocysta pastielsi*, *Thalassiphora pelagica*, *Cordosphaeridium funiculatum*, (Pls. VI–XI; Fig. 3). The preparations contain neither foraminiferal linings nor glauconite grains.

The above-presented assemblage is typical of the Lower Oligocene — Rupelian deposits, developed as the Czempin Formation.

ŁOSINY 2/KB

Three phytoplankton assemblages have been identified within the 50 m-thick Paleogene deposits (Fig. 4). The oldest assemblage comes from sandy silts encountered at a depth of 192.60–192.65 m.

Sporomorphs are scarce here. Marine phytoplankton is significant and abundant, and represented among others by: *Alisocysta*, *Apteodinium*, *Cerodinium depressum*, *C. speciosum*, *C. striatum*, *Membranosphaera*, *Fibradinium annetorpense*, *Glaphyrocysta semitecta*, *Isabelidinium* ? *vibrogense*, *Lithosphaeridium*, *Palaeocystodinium-Andalusiella*, *Palaeocystodinium* cf. *denticulata*, *Palaeoperidinium pyrophorum*, *Palambages morulosa*, *Paleotetradinium minusculum*, *Phanerodinium* cf. *carinatum*, *Ph. sequonosum*, *Pterospermella australiensis*, (Pls. I–V; Fig. 4).

This phytoplankton assemblage composition indicates Middle Paleocene — Selandian deposits developed as the Odra Formation.

The second phytoplankton assemblage originates from silt-sand deposits from a depth of 161.15–190.45 m. The occurrence frequency of sporomorphs is high. The abundant marine phytoplankton assemblage is represented by: *Chiropteridium lobospinosum*, *Phthanoperidinium amoenum*, *Membranophoridium aspinatum*, *Pentadinium laticinctum*, *Wetzeliiella symmetrica*, *W. meckelfeldensis*, *Cordosphaeridium inodes*, *Enneadocysta*

Table 1

Results of the phytoplankton studies of other profiles analysed by the author¹

Borehole	Depth	Characteristic taxa in phytoplankton assemblages	Age	Lithostratigraphy
Raciąż	193.00–210.00	<i>Chiropteridium</i> , <i>Deflandrea</i> , <i>Homotryblum</i> , <i>Spiniferites</i> , <i>Wetzeliiella</i> , <i>Tetrapidites</i> , <i>Botryococcus</i>	Lower Oligocene	Czempin Formation
Tuchola-Białowieża VI	114.00–172.00	<i>Paucilobomorpha incurvata</i> , <i>Homotryblum</i> , <i>Wetzeliiella</i> , <i>Spiniferites</i> , <i>Michrystidium</i> , <i>Deflandrea phosphoritica</i> , <i>Glaphyrocysta pastielsii</i> , <i>Tetrapidites</i> , <i>Sigmozygoidites</i>	Lower Oligocene	Czempin Formation
Wymysłowo XI	84.50–89.10	<i>Chiropteridium</i> , <i>Homotryblum</i> , <i>Phthanoperidinium</i> , <i>Wetzeliiella</i> , <i>Tetrapidites</i> , <i>Sigmopollis</i>	Lower Oligocene	Czempin Formation
Obrowo III	159.00–168.60	<i>Wetzeliiella</i> , <i>Chiropteridium</i> , <i>Homotryblum</i> , <i>Spiniferites</i> , <i>Michrystidium</i> , <i>Sigmopollis pseudosetarius</i>	Upper Eocene	Pomorze Formation
	64.00–65.00	<i>Deflandrea</i> , <i>Homotryblum</i> , <i>Chiropteridium</i> , <i>Wetzeliiella</i> , <i>Crassosphaera</i>	Lower Oligocene	Czempin Formation
Mędromierz V	173.20–175.60	<i>Homotryblum</i> , <i>Spiniferites</i>	Upper Oligocene	Upper Mosina Formation
	87.00–100.60	<i>Chiropteridium</i> , <i>Michrystidium</i> , <i>Paucilobomorpha</i> , <i>Wetzeliiella</i> , <i>Spiniferites</i> , <i>Deflandrea phosphoritica</i> , <i>Homotryblum</i> , <i>Crassosphaera</i> , <i>Sigmopollis pseudosetarius</i>	Upper Eocene/ Lower Oligocene	Lower Mosina Formation
Jeleńcz IV	157.10–160.00	<i>Chiropteridium</i> , <i>Homotryblum</i> , <i>Spiniferites</i> , <i>Wetzeliiella</i> , <i>Crassosphaera</i> , <i>Sigmopollis pseudosetarius</i>	Lower Oligocene	Czempin Formation
Kamień 2/Ka	207.50–207.60	<i>Enneadocysta pectiniformis</i> , <i>Cordosphaeridium funiculatum</i> , <i>Lingulodinium machaerophorum</i>	Upper Eocene/ Lower Oligocene	Lower Mosina Formation
	161.70–167.80	<i>Deflandrea phosphoritica</i> , <i>Dapsilidinium simplex</i> , <i>Rhombodinium longimanum</i> , <i>Thalassiphora pelagica</i> , <i>Wetzeliiella symmetrica incisa</i>	Lower Oligocene	Czempin Formation
Piła- Młyn V	173.70–174.70	<i>Thalassiphora pelagica</i> , <i>Crassosphaera</i> , <i>Chiropteridium</i> , <i>Cymatiosphaera</i> , <i>Wetzeliiella</i> , <i>Spiniferites</i> , <i>Homotryblum</i>	Lower Oligocene	Czempin Formation
Gostycyn IV	162.40–163.00 155.00–156.00	<i>Chiropteridium lobospinosum</i> , <i>Hystrichokolpoma rigaudiae</i> , <i>Homotryblum tenuispinosum</i> , <i>Phthanoperidinium</i> , <i>Polysphaeridium</i> , <i>Spiniferites ramosus</i> , <i>Thalassiphora pelagica</i> , <i>Wetzeliiella</i> , <i>Crassosphaera</i>	Lower Oligocene	Czempin Formation

Table 2

Results of the phytoplankton other authors studies (archival profiles)¹

Borehole Author	Depth	Characteristic taxa in phytoplankton assemblages	Age	Lithostratigraphy
Kłodawa 4/Kł Ważyńska, 1987b	274.00	<i>Chiropteridium</i> , <i>Cordosphaeridium</i> , <i>Paucilobomorpha incurvata</i>	Upper Eocene/ Lower Oligocene	Lower Mosina Formation
	245.00–270.50	<i>Chiropteridium lobospinosum</i> , <i>Membranophoridium aspinatum</i> , <i>Wetzeliiella symmetrica</i>	Lower Oligocene	Czempin Formation
Kłodawa 5/Kł Ważyńska, 1987a	242.70–242.80	<i>Baltisphaeridium</i> , <i>Chiropteridium</i> , <i>Botryococcus</i> , <i>Hystrichokolpoma</i> , <i>Homotryblum tenuispinosum</i> , <i>Leiosphaeridia</i> , <i>Michrystidium</i> , <i>Operculodinium</i>	Upper Eocene/ Lower Oligocene	Lower Mosina Formation
	178.50–225.20	<i>Chiropteridium lobospinosum</i> , <i>Membranophoridium aspinatum</i> , <i>Wetzeliiella symmetrica</i>	Lower Oligocene	Czempin Formation
Łyskowo PG 1 Rębas, 1984	70.40–170.20	<i>Chiropteridium lobospinosum</i> , <i>Membranophoridium aspinatum</i> , <i>Deflandrea phosphoritica</i> , <i>Enneadocysta pectiniformis</i> , <i>Wetzeliiella</i>	Lower Oligocene	Czempin Formation
Wilcze IG 1 Grabowska, 1985	145.00–175.00	<i>Deflandrea phosphoritica</i> , <i>Wetzeliiella symmetrica</i> , <i>Membranophoridium aspinatum</i> , <i>Chiropteridium lobospinosum</i>	Lower Oligocene	Czempin Formation

¹All archival palynological elaborates from the study area were analysed in details and then revised.

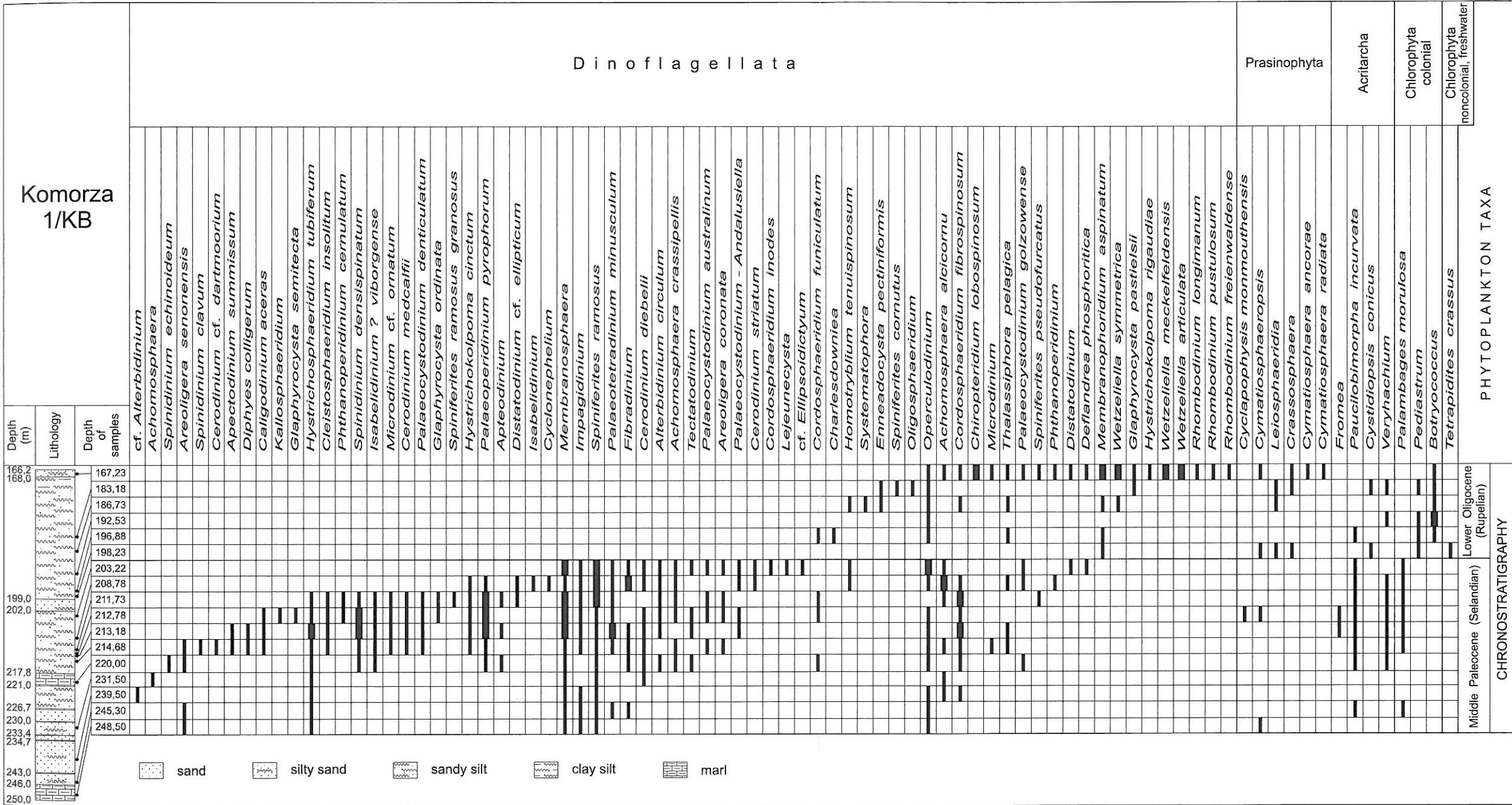


Fig. 3. Distribution of Paleogene phytoplankton in Komorza 1/KB borehole

pectiniformis, *Spiniferites pseudofurcatus*, *S. cornutus*, *Thalassiphora pelagica*, *Deflandrea phosphoritica*, *Paleocystodinium golzowense*, (Pls. VI–XI; Fig. 4). It is typical of the Lower Oligocene — Rupelian deposits, developed as the Czempin Formation.

The last assemblage has been identified in clayey silts from a depth of 144.10–144.15 m, which are separated from deposits containing the previous assemblage by a 16 m-thick sand series.

The assemblage contains poorly preserved marine phytoplankton, among others: *Chiropteridium lobospinosum*, *Membranophoridium aspinatum*, *Rhombodinium* cf. *pustulosum*, *Wetzeliiella meckelfeldensis* (Fig. 4). The taxonomic composition does not unambiguously indicate the age of this assemblage. However, it can be suggested that it represents the upper part of Oligocene (Upper Oligocene — Chattian, Upper Mosina Formation).

PHYTOPLANKTON-BASED PALEOGENE PALYNOSTRATIGRAPHY OF THE POMERANIAN LAKE LAND

The varying contribution of phytoplankton allows for identification and precise dating of Paleogene assemblages in marine deposits from the Tuchola region. Spore-pollen assemblages, found in these deposits, provide much less accurate stratigraphical datings because pollen material, derived from distant land areas, tends to be sorted out. Therefore, phytoplankton is the best palynostratigraphical tool to investigate these deposits.

The identified phytoplankton assemblages from all the sections in the Tuchola region have been correlated with dinoflagellate zones, and lithostratigraphic and chronostratigraphic schemes (Table 3). They are also presented against the background of dinocyst schemes from western Europe (Table 4).

PALEOCENE

Paleocene deposits of Poland, dated on the basis of palynological investigations, are known to now from two regions: south-eastern Poland near Puławy, and north-western Poland near Szczecin (Fig. 5).

In south-eastern Poland Paleocene deposits were first documented palynologically by Moroz (1970) in two exposures located near Puławy at Bochoznica and Nasiłów villages. These deposits are included within the Puławy/Odra Formation and are represented by the so-called „siwak series” composed of marly gaizes with grey limestone interbeds. They contain Lower Paleocene pollen flora abundantly represented by Normapolles (12 species). There are also numerous Dinoflagellata represented by peridinioid and gonyaulacoid dinocysts. This floral assemblage can be correlated with the floral zone 6–7 of Krutzsch (1966), and located in the upper part of Middle Paleocene (Montian, partly Selandian). Hansen *et al.* (1989) determined the age of the Nasiłów „siwak series” to be earliest Danian, basing on the index species of *Senoniasphaera inornata* (Drug) Stover, Evitt, 1978. Occurrence of dinocysts typical of the Danian, studying the northern and western margins of the Lublin Upland was reported by Gedl (1999). Danian dinocysts assemblage was also describe from Kamienny Dół outcrop near Kazimierz Dolny (Słodkowska, 2003).

In north-western Poland Paleocene palynological assemblages are known from the boreholes Szczecin IG 1, Goleniów IG 1 (Grabowska, 1968, 1974) and Goleniów IG 2 (Grabowska, 1983). No marine phytoplankton has been found among palynomorphs from lignites and lignite clays encountered in the Szczecin IG 1 and Goleniów IG 1 boreholes. On the basis of sporomorphs, including Normapolles pollen grains

(9 species), the assemblages have been assigned to the Odra Formation. The presence of only sporomorphs indicates a continental depositional environment.

In the nearby located Goleniów IG 2 borehole occur Paleocene marine deposits represented by sands containing numerous Normapolles (13 species). The marine environment is evidenced by the abundant phytoplankton assemblage containing important taxa such as: *Cerodinium diebelii*, *Spinidinium densispinatum*, *Palaeoperidinium pyrophorum*, *Pterospermella australiensis* and other numerous dinocyst species. The assemblage is dated as Paleocene (not further subdivided) (Grabowska, 1983).

The present studies of the abundant marine phytoplankton assemblage from the Komorza 1/KB and Łosiny 2/KB boreholes have enabled dating of Paleocene deposits. The Paleocene phytoplankton assemblage, found in sandy silts and marls of the Komorza 1/KB borehole (depth 203.22–248.50 m) and in sandy silts of the Łosiny 2/KB borehole (depth 192.63 m), was the first described from Poland. A more complete Paleocene succession is known from the 45 m-thick section of the Komorza 1/KB borehole.

The identified palynomorph assemblage contains a small percentage of spores and pollen grains, and majority of Normapolles specimens (14 species). The most distinctive feature of this assemblage is its high taxonomic diversity and abundance of marine phytoplankton specimens. The phytoplankton assemblage composition, including the characteristic taxa of *Alterbidinium*, *Cerodinium* cf. *dartmoorium*, *Apectodinium summisum*, *Diphyes colligerum*, *Cyclapophysis monmouthensis*, *Spinidinium densispinatum*, *Isabelidinium? viborgense*, *Palaeoperidinium pyrophorum*, *Palaeotetradinium minusculum*, *Fibradinium*, *Cerodinium diebelii*, *Alterbidinium circulum*, *Palaeocystodinium australinum*, *Cerodinium striatum*, *Alisocysta*, *Cerodinium speciosum*, *C. depressum*, *Microdinium reticulatum*, enables correlations (Table 4) with similar assemblages of Denmark (Heilmann-Clausen, 1985) and Germany (Köthe, 1990) (Pls. I–V).

The identified genera and species can be correlated with taxa that occur in zones 1, 2 and 3 of the stratotype section Viborg 1, Denmark (Heilmann-Clausen, 1985; Table 4). The assemblage with *Cyclapophysis monmouthensis* from the Komorza 1/KB borehole can be correlated with Zone 1. Both the Komorza 1/KB and Łosiny 2/KB sections contain *Isabelidinium? viborgense* and *Alisocysta* sp. 1 Heilmann-Clausen (first appearance), characteristic of Zone 2. Zone 3 is defined by the first

Table 3

Stratigraphical position of profiles from Tuchola region

Komorza 1/KB	Łosiny 2/KB	Raciaz II	Tuchola-Białowieża VI	Wymysłowo XI	Obrowo III	Mędromierz V	Jeleń IV	Kamień 2/KB	Piła Młyn V	Gostycyn IV	Kłodawa 4/Kt	Kłodawa 5/Kt	Mysłogosz 1	Gronowo 2	Gronowo 3	Łyskowo PG 1	Wilcze IG 1	Dinoflagellate zonation (Powell, 1992)	Lithostratigraphy (Piwocki, 1998)	Chronostratigraphy
	+					+												D14/D15	Upper Mosina Fm.	Upper Oligocene (Chattian)
+	+	+	+	+	+		+	+	+	+	+	+	+	+	+	+	+	D14	Czempin Formation	Lower Oligocene (Rupelian)
						+		+			+	+						D12/D13	Lower Mosina Fm.	Upper Eocene/Lower Oligocene
																		D12	Pomorze Formation	Upper Eocene (Prabonian)
+	+																	D3-D4	Odra Formation	Middle Paleocene (Selandian)

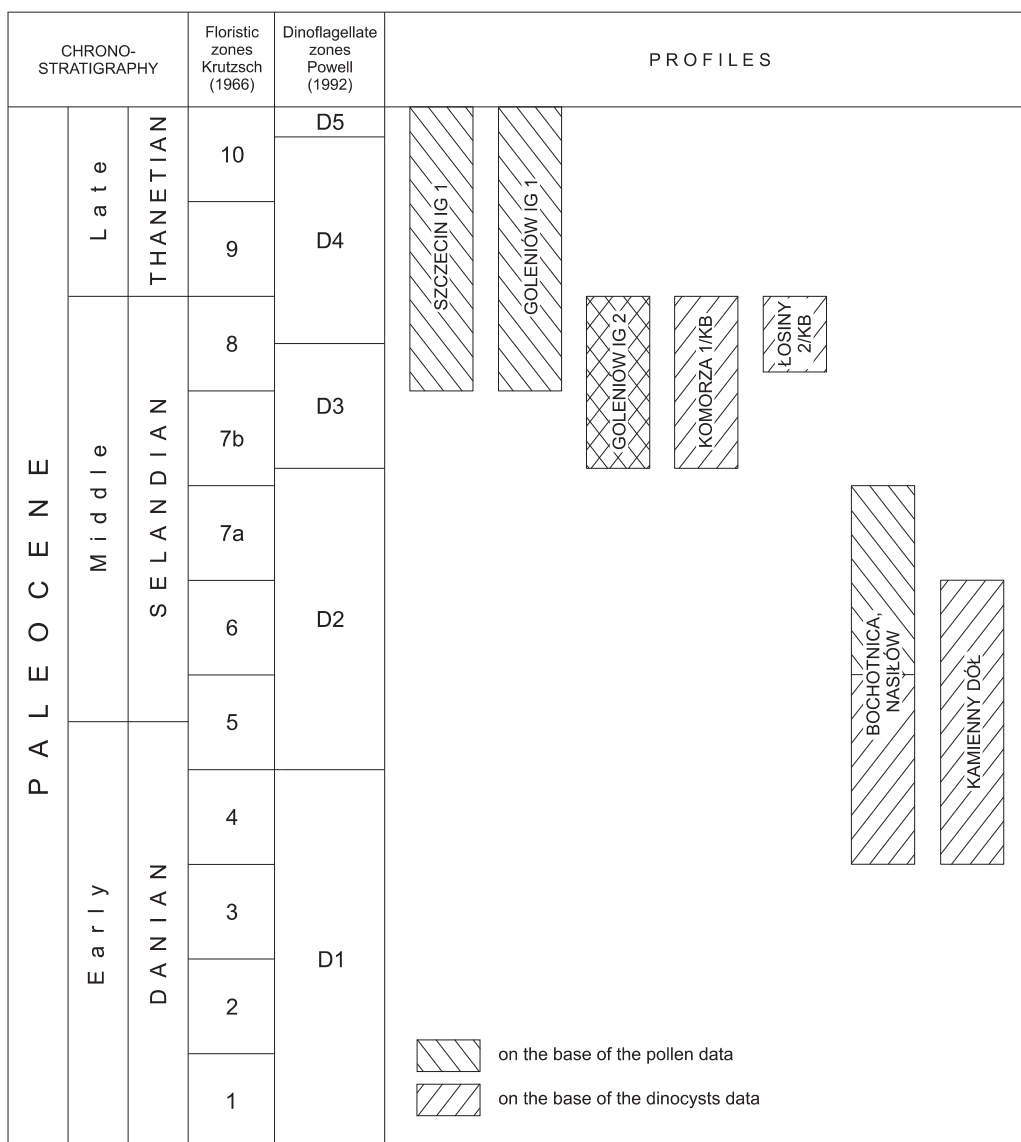


Fig. 5. Stratigraphical position of Paleocene palynological profiles of Poland

Paleogene dinocyst zonation of the study area against the background of Paleogene zonation from north-western Europe
(after Stover *et al.*, 1996 — modified)

(GTS, 2004)		DENMARK	NORTHWESTERN EUROPE		GERMANY		NORTHWESTERN EUROPE		NORTHWESTERN POLAND			
Ma	Age	Heilmann-Clausen (1985)	Costa & Manum (1988)		Köthe (1990)		Powell (1992)		Ślodkowska (this paper)			
	CHATTIAN		D15		D15		D15	Hfl	D15	<i>Membranophoridium aspinatum</i> <i>Wetzeliiella meckelfeldensis</i> <i>Chiropteridium lobospinosum</i> <i>Rhombodinium pustulosum</i> <i>Phthanoperidinium</i> <i>Cymatiosphaera bleawykensis</i> <i>Cymatiosphaera delicata</i>		
30	RUPELIAN		D14		D14	nb	D14	Lxa	D14		<i>Chiropteridium lobospinosum</i> <i>Membranophoridium aspinatum</i> <i>Cordosphaeridium inodes</i> <i>Wetzeliiella symmetrica</i> <i>Rhombodinium longimanum</i> <i>Rhombodinium pustulosum</i> <i>Glaphyrocysta pastielsii</i>	
								Pcr				
35	PRIABONIAN		D13		D13		D13	Wgo	D12- D13			<i>Enneadocysta pectiniformis</i> <i>Cordosphaeridium funiculatum</i> <i>Lingulodinium machaerophorum</i> <i>Paucilobimorpha incurvata</i> <i>Michrystidium</i>
40	BARTONIAN		D12		D12	nc nb na	D12	Rpe	D12	<i>Wetzeliiella</i> <i>Chiropteridium</i> <i>Homotryblium</i> <i>Spiniferites</i> <i>Michrystidium</i>		
45	LUTETIAN		D11		D11		D11	Wsi				
								Rpo				
50	YPRESIAN		D10		D10		D10	Rdr				
								Gin				
55			D9		D9	nb	D9	Aar				
								Pco				
60	THANETIAN		D8		D8	na	D8	Pla	D3- D4			<i>Palaeotetradinium minusculum</i> <i>Isabelidium ? viborgense</i> <i>Cerodinium speciosum</i> <i>Palaeoperidinium pyrophorum</i> <i>Cerodinium cf. dartmoorium</i> <i>Spinidium densispinatum</i> <i>Cyclapophysis monmouthensis</i> <i>Alterbidinium circulum</i>
								Ccl				
65			D7		D7	nb na b a	D7	Dva/si				
								Wme/Was				
70			D6		D6	b a	D6	Gor				
								Aau				
75			D5		D5	b a	D5	Ahy				
								Ama				
80	THANETIAN		D4		D4	nb na	D4	Ppy				
								Csp				
85			D3		D3	nc nb na	D3	Sde				
								Cst				
90	DANIAN		D2		D2		D2	Scr				
								Xlu				
95			D1		D1		D1	Tru				
								Cco				

appearance of *Cerodinium striatum*, *Palaeocystodinium australinum* and, in the lower part, *Diphyes colligerum*. Zones 2 and 3 of the Viborg 1 section contain abundant *Palaeoperidinium pyrophorum*. All the above-mentioned species have been identified in the Komorza 1/KB and Łosiny 2/KB boreholes, thus defining the assemblage as correlatable with these three zones of the Viborg 1 section.

The phytoplankton assemblages from Komorza 1/KB and Łosiny 2/KB sections can be correlated with assemblages identified in the Söhlingen H1 and Pennigsehl P1 sections of Germany (Lower Saxony) (Köthe, 1990). The Polish assemblages were compared with zones D3nb, D3nc and D4na, distinguished by Köthe (1990). In the Zone D3nb, *Spinidinium densispinatum* appears first and last time. This species was found in the Komorza 1/KB section. In Zone D3nc *Spinidinium densispinatum* appears for the last time. At top of this zone, there is the first occurrence of *Cerodinium speciosum*. *Palaeoperidinium pyrophorum* is abundant in both these zones, and also in overlying Zone D4na. The Paleocene phytoplankton assemblages from Komorza 1/KB and Łosiny 2/KB sections can be correlated with Zone D4na, starting from the first occurrence of *Cerodinium speciosum* up to the last occurrence of *Cerodinium striatum*.

The phytoplankton assemblage, identified in material derived from the Komorza 1/KB and Łosiny 2/KB boreholes, spans Zones 1, 2 and 3 of the Viborg 1 section (Heilmann-Clausen, 1985), and zones D3nb, D3nc, D4na of the German sections (Köthe, 1990).

Variations, that give rise to the zonation, are not very distinct in the analysed sections and the threefold division is poorly accentuated here. It refers in particular to the 45 m-thick interval from the Komorza 1/KB section. The phytoplankton assemblage from the Łosiny 2/KB section can be correlated with the upper part of the Komorza 1/KB assemblage. The Łosiny 2/KB section does not contain the species *Spinidinium densispinatum*, typical of the lower zone (Zone 1, Viborg 1). The remaining taxa from the Łosiny 2/KB section are more frequent in the two upper Zones of the stratotype sections (Viborg 1, Söhlingen H1 and Pennigsehl P1).

According to the dinocyst scheme of Powell (1992) the phytoplankton assemblage from the Komorza 1/KB and Łosiny 2/KB sections, containing characteristic species, belongs to Zone D3 and, in part, to the lowermost portion of Zone D4 (Table 4).

The phytoplankton assemblage is dated as the Middle Paleocene — Selandian (Table 4), corresponding to Zones D3 Sde, D3 Csp and D4 Ppy (Powell, 1992). In the correlation table showing Dinoflagellata zonations proposed by various authors, Heilmann-Clausen (1985) located Zone 1 of the Viborg 1 section in the upper Danian. According to Köthe (1990), to Danian also rank Zone D3 nb. These zones correspond to Zone D3 Sde, which was included by Powell (1992) within the Thanetian. According to Heilmann-Clausen (1985) and Köthe (1990), the Danian and Thanetian boundary runs between Zones 1 and 2 in the Viborg 1 borehole or between Zones D3nb and D3nc of the German sections. Recently, after the Geologic

Time Scale (2004), the threefold division of the Paleocene, these assemblages correspond to the Middle Paleocene — Selandian between 58,7–61,7 Ma. The most reasonable solution to assign the assemblage from the lowermost part of the Komorza 1/KB section to the Selandian, i.e. to Zone D3 Sde according to the scheme of Powell (1992). The upper part of the Komorza 1/KB assemblage as well as the assemblage from the Łosiny 2/KB section — zones D3 Csp and D4 Ppy (Tables 3, 4) — also belong to the upper part of Selandian and lowermost Thanetian. In the lithostratigraphic scheme, the assemblages should be assigned to the Odra Formation.

EOCENE

The Lower and Middle Eocene phytoplankton assemblages have been not found in the analysed sections.

Upper Eocene

The Upper Eocene palynomorph assemblage has been found only in the Obrowo III borehole where fairly abundant pollen grains are accompanied by marine phytoplankton, including *Wetzeliella*, *Chiropteridium*, *Homotryblum*, *Spiniferites* and *Micrhystridium*. The age of this assemblage cannot be precisely defined due to the lack of the index species *Rhombodinium perforatum*, however, most probably it represents the Upper Eocene, lithostratigraphically corresponding to the Pomorze Formation. The assemblage is correlatable with spectra from northern Poland (Grabowska, 1987; Grabowska, Ważyńska, 1997) and it corresponds to the spectrum image of Zone D12 (Costa, Manum, 1988), and also to the middle part of Zone D12nb (Köthe, 1990). The assemblage can also be correlated with part of Zone D12 Rpe of (Powell, 1992; Tables 3, 4).

Upper Eocene/Lower Oligocene

The Upper Eocene/Lower Oligocene phytoplankton assemblage has been identified in the Kłodawa 4/Kł (Ważyńska, 1987a), Kłodawa 5/Kł (Ważyńska, 1987b), Kamień 1/KA and Mędromierz V boreholes. It contains a number of index taxa represented by *Enneadocysta pectiniformis*, *Cordosphaeridium funiculatum*, *Lingulodinium machaerophorum*, *Paucilobimorpha incurvata* and *Micrhystridium*. This is the Upper Eocene/Lower Oligocene transitional assemblage. It should be assigned to the Lower Mosina Formation and correlated with similar assemblages from northern Poland (Grabowska, 1987; Grabowska, Ważyńska, 1997). This phytoplankton assemblage (Tables 4) can be assigned to Zone D12nc/D13 defined by Köthe (1990), and to the upper part of Zone D12 and Zone D13 (Powell, 1992) (Tables 3, 4).

OLIGOCENE

Lower Oligocene

Deposits associated with sedimentation of the V Czempin Lignite Seam occur near Tuchola. Also south of the study area, in the Bydgoszcz–Bąkowo–Radojewice region, Lower Oligocene paralic deposits contain lignites of the V Czempin Seam (Piwocki, 1992).

The Lower Oligocene — Rupelian phytoplankton assemblage is the marker horizon for correlations across the Pomeranian Lakeland. This assemblage has been identified in the following 17 boreholes: Myśligoszcz 1, Gronowo 2, Gronowo 3 (Mamczar, 1963), Łyskowo PG 1 (Rębas, 1984), Wilcze IG 1 (Grabowska, 1985), Kłodawa 4/Kł, (Ważyńska, 1987a), Kłodawa 5/Kł (Ważyńska, 1987b), Komorza 1/KB, Łosiny 2/KB, Raciąż II, Tuchola-Białowieża VI, Wymysłowo 11, Obrowo III, Jeleń IV, Kamień 2/KA, Piła-Młyn V and Gostycyn IV. This assemblage contains the index taxa of *Chiropteridium lobospinosum*, *Membranophoridium aspinatum*, *Cordosphaeridium inodes*, *Wetzeliiella symmetrica*, *Rhombodinium longimanum*, *R. pustulosum* and *Glaphyrocysta pastielsii*. The Lower Oligocene phytoplankton assemblages can be correlated with widespread assemblages identified in the Rupelian/Czempin Formation of the Polish Low-

lands (Grabowska, 1965, 1987; Grabowska, Piwocki, 1975; Słodkowska, 1995; Grabowska, Ważyńska, 1997). This phytoplankton composition corresponds to the spectrum image of Zone D14na (Köthe, 1990). It can also correspond (Table 4) to the lowermost part of Zone D14 (Powell, 1992) (Pls. VI–XI, Tables 3, 4).

Upper Oligocene

The Upper Oligocene palynomorph assemblage has been found in the Łosiny 2/KB and Mędromierz V boreholes. This assemblage contains single specimens of Paleogene phytoplankton, among others: *Membranophoridium aspinatum*, *Wetzeliiella meckelfeldensis*, *Chiropteridium lobospinosum*, *Rhombodinium pustulosum*, *Phthanoperidinium*, *Cymatosphaera bleawykensis* and *C. delicata*. These forms indicate an Upper Oligocene (Chattian) age of the assemblage that is characteristic of the Upper Mosina Formation. Similar spectra were obtained from the Brachnowo 35/93 borehole drilled near Toruń (Grabowska, 1970b; Grabowska, Piwocki, 1975). The identified assemblage can be approximately correlated with the uppermost part of Zone D14nb and Zone D15 (Köthe, 1990), or, according to the Powell scheme (1992), with the upper part of Zone D14 and Zone D15. Therefore, this assemblage corresponds to Zone Hfl (Powell, 1992) (Tables 3, 4).

SEDIMENTARY CONDITIONS OF PALEOGENE MARINE DEPOSITS RECONSTRUCTED FROM PHYTOPLANKTON

ECOLOGICAL PHYTOPLANKTON GROUPS IN PALEOGENE DEPOSITS

The phytoplankton analysis aimed at the identification of ecological groups in order to reconstruct sedimentary conditions in the study area during the Paleogene. The analysis was performed on palynological material from the Komorza 1/KB and Łosiny 2/KB boreholes. All taxa identified in all boreholes are shown in Appendix A. The table also contains some remarks on the conditions in which the taxa most frequently exist, derived from the available literature. The following environmental factors have been determined: sedimentary environment, dominant facies, distance from land, and water salinity and temperature (Downie *et al.*, 1971; Harland, 1973, 1983; Islam, 1984; Köthe, 1990; Brinkhuis, 1994; Tyson, 1995; Stover *et al.*, 1996). Many of these authors proposed a subdivision of phytoplankton into ecological groups, taking into account different environmental factors. Basing mainly on the division of Köthe (1990) and the author's own observations, six phytoplankton groups have been distinguished. They are typical of given sedimentary conditions. These groups were characterized according to the following scheme: division Dinoflagellata — including gonyaulacoid and peridinioid dinocysts; division Prasinophyta, Acritarcha group,

division Chlorophyta with colonial Chlorophyta (brackish and freshwater) and noncolonial Chlorophyta (freshwater).

Dinoflagellata, gonyaulacoid dinocysts (Dg). Autotrophic, photosynthetic species. They live in outer shelf waters of the open-marine environment. These forms commonly possess processes (*chorate*, *proximochorate*) on their surface. In Paleogene sections they are most often represented by *Achomosphaera*, *Cordosphaeridium*, *Hystrichosphaeridium*, *Systematophora*, and also *Impagidinium* — a remarkably oceanic genus. These taxa are usually present in transgressive sequences of the sections. They show much tolerance with respect to temperature. Species that live in normal salinity waters are dominant here.

Brinkhuis (1994) reports a gonyaulacoid succession from taxa that settle in nearshore habitats to those living in the oceanic abyss: *Homotryblum* → *Areoligera*/*Glaphyrocysta* → *Operculodinium* → *Areosphaeridium*/*Spiniferites* → *Impagidinium*.

Dinoflagellata, peridinioid dinocysts (Dp). Presumably heterotrophic species settled the eutrophic waters, prefer estuarine and lagoonal environments, shallow water and brackish basins. Peridinioid dinocysts are most frequently represented by forms with the free space between the inner and outer cyst wall — *cavate*. Thick-walled forms, resistant to high en-

ergy of marine waters (strong waves), predominante in nearshore environments. These organisms tolerate a wide temperature range, although they occur most frequently in cooler and nutrient-rich waters. The most typical Paleogene representatives of this group are *Wetzelia*, *Deflandrea*, *Phthanoperidinium* and *Apectodinium*, characteristic of the inner shelf, as well as the genera *Charlesdownia* and *Rhombodinium*, more common on the outer shelf.

Prasinophyta (P) occur most frequently in nearshore basin zones, in quiet and low-salinity waters, although they are sometimes observed in other zones of the shelf. Their occurrence is associated with stable hydrodynamic conditions. Deposits, in which they occur, contain components derived from freshwater facies. Each of the taxa *Leiosphaeridia*, *Crassosphaera*, *Pterospermella* and *Cymatiosphaera* shows different preferences regarding distance from the land. Nevertheless, Prasinophyta have been reported mostly from various zones of the shelf, thus being an indicator of shelf facies.

Acrirarcha (A) — representatives of this polyphyletic plankton group frequently occur in shallow-marine basin zones (inner shelf). These organisms are resistant to mechanical and chemical factors. The genus *Veryhachium*, for instance, can live in waters of wide salinity range. Representatives of the genus *Micrhystridium* occur in inner shelf environments ranging from brackish through lagoonal to estuarine. They are an indicator of the beginning or ending of a transgressive-regressive cycle.

Colonial, multicellular Chlorophyta (Chm) occur in both brackish and freshwater environments. *Botryococcus* is a cosmopolitan genus inhabiting a variety of environments in different climatic zones. The genus can be found in both lake and river waters of variable chemistry and pH. It also occurs in salt lakes and lagoons, in brackish and deltaic facies. The genus *Pediastrum* occurs in more freshwater environments. It prefers inland lake waters, but can also appear in swamps. The genus is rare in nearshore and shelf environments. In marine deposits it can occur as a redeposited component transported, for example, to the outer zone of delta.

Noncolonial, unicellular, freshwater Chlorophyta (Chun). They occur exclusively in continental basins and can be abundant in lacustrine and swamp facies. Frequent occurrence of specimens from the family Zygnemataceae and genus *Ovoidites* indicate continental facies and deposition in freshwater basins. If they are found in marine deposits, then they should be regarded as a redeposited component of phytoplankton.

The identification of these phytoplankton groups allows a reconstruction of depositional environments. Not all of the taxa can be precisely classified into a given group, e.g. the gonyaulacoid cyst genus *Homotryblium* occurs in nearshore facies, in higher salinity waters. Islam (1984) observed in this genus a dependence between the length of processes and distance from land. Species with longer processes prefer deeper waters, those with shorter ones live in nearshore zones.

The analysis of the contribution of individual ecological groups of phytoplankton from the Komorza 1/KB and Łosiny 2/KB boreholes were performed. Rich material — a total of 136 taxa (Appendix A) — gave rise to both the construction of graphs illustrating contribution of individual phytoplankton groups in the Paleogene section of each borehole, and the reconstruction of succession of these groups. It allows to draw palaeoenvironmental

conclusions (Fig. 6). To construct the graphs, a relationship between the total number of taxa in each group to the number of all taxa identified in the sample was calculated. Single samples or sample groups, showing a similar contribution of individual phytoplankton groups, were joined to form local phytoplankton assemblages. These assemblages are labelled with the first letter of the borehole name followed by the roman number.

Komorza 1/KB

The analysis of succession of the phytoplankton groups from the Komorza 1/KB borehole enabled the reconstruction of depositional conditions during the Middle Paleocene and Early Eocene (Fig. 6). Inferring from the dominant occurrence of gonyaulacoid type of cyst (80%) and minority of Prasinophyta (20%) in deposits from a depth of 248.50 m, it can be assumed that the basin had a normal salinity at those times. The lack of components derived from land indicates the distal zone of outer shelf.

Gonyaulacoid dinocysts are also predominant (67%) in deposits from a depth of 245.30 m, with a smaller contribution of Acrirarcha (8%) and colonial Chlorophyta (8%), indicating a slight shallowing of the basin. The deposition took place in the proximal zone of outer shelf.

Gonyaulacoid dinocysts were the only specimens found at a depth of 239.50 m. It indicates a deepening of the marine basin, normal salinity waters and deposition in the distal, deeper zone of outer shelf.

Deposits from a depth of 231.50 m still provide evidence for open-marine conditions confirmed by the sole occurrence of Dinoflagellata with remarkable dominance of gonyaulacoid cysts (80%), and the presence of peridinioids (20%). These proportions suggest deposition in the distal zone of outer shelf, although little contribution of shallow-water species is accentuated.

The above-described assemblages were joined into one local phytoplankton assemblage accumulated in the deeper zone of outer shelf and labelled as K I.

Phytoplankton identified at a depth of 220.00 m shows a decreasing percentage contribution of gonyaulacoid cysts (58%), higher percentage of peridinioid cysts (32%), and the appearance of Acrirarcha (10%). It indicates a shallowing of the basin and predominance proximal zone of outer shelf facies. A very similar facies type is also observed at depths of 214.68 and 213.18 m. Proportions between individual phytoplankton groups are more or less equal. There is also little contribution of colonial Chlorophyta (3%). Therefore, both these assemblages from a depth of 213.18–220.00 m can be joined to form another local phytoplankton assemblage labelled as K II and characteristic for the proximal zone of the outer shelf.

A slight shallowing of the environment and freshwater influx into the basin is recorded at a depth of 212.78 m. The phytoplankton assemblage contains less gonyaulacoid cysts (46%), somewhat more peridinioid cysts (36%), similar amount of Acrirarcha (10%), and rare Prasinophyta (3%). The percentage of colonial Chlorophyta (3%) is similar as in the underlying deposits. This assemblage, containing slightly more phytoplankton specimens characteristic of shallower shelf zones, is labelled as K III.

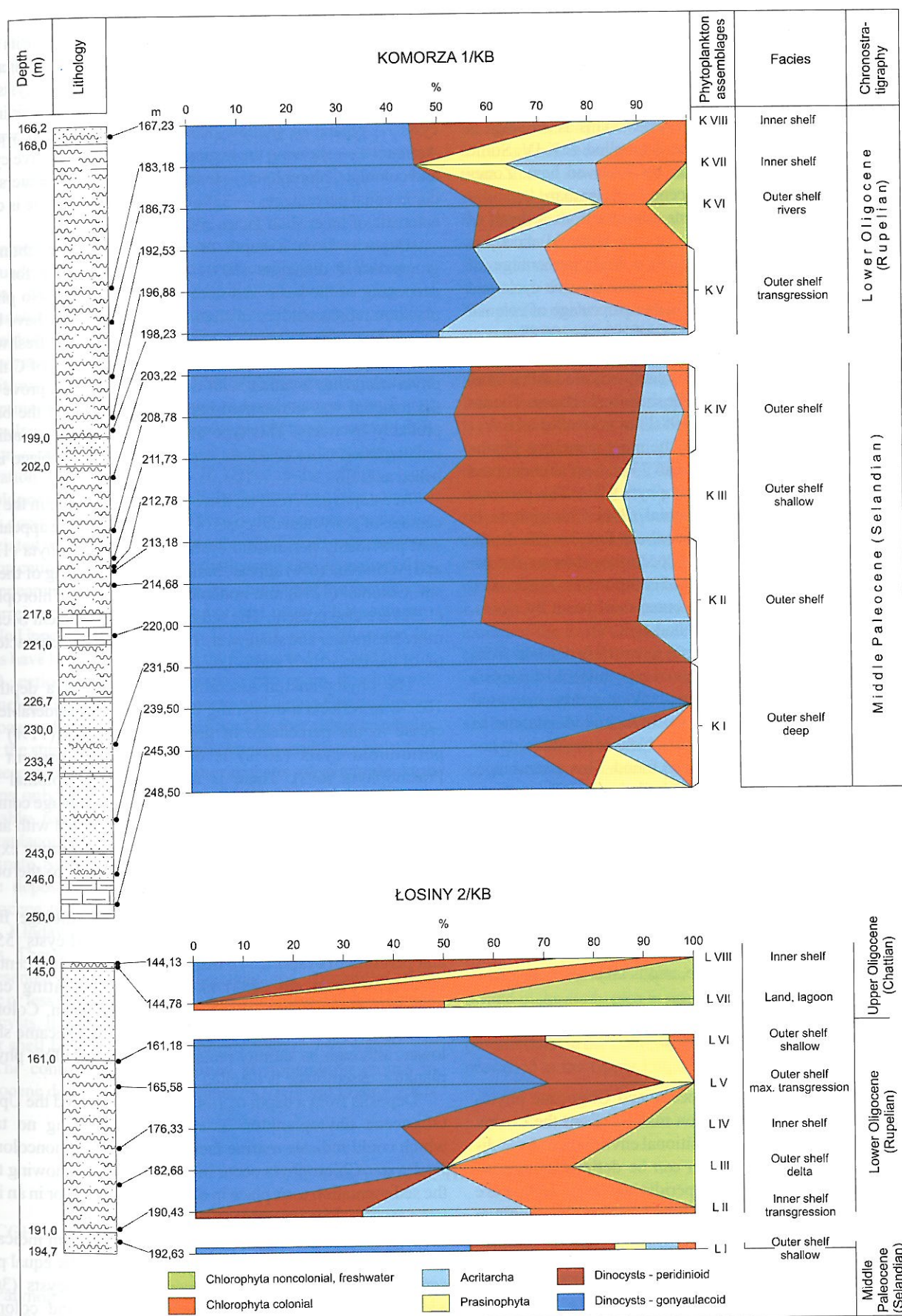


Fig. 6. Phytoplankton groups in Paleogene deposits from Komorza 1/KB and Łosiny 2/KB boreholes

The phytoplankton groups from a depth of 203.22–211.79 m, containing dominant gonyaulacoid dinocysts (55% on average), peridinioid cysts (35%) and *Acrirarcha* (7%), and with little percentage of colonial *Chlorophyta* (4%), indicate a stable marine sedimentary environment. This assemblage is characteristic of the outer shelf and is labelled as K IV. Some analogous to assemblage K II can be observed here. Zones K I–K IV represents Middle Paleocene — Selandian.

The overlying Lower Oligocene deposits from a depth of 198.23 m contain equal amounts of gonyaulacoid dinocysts (50%) and *Acrirarcha* (50%). Such a high percentage of *Acrirarcha* indicates the beginning of a transgressive cycle and predominance of marine facies. A higher percentage of colonial *Chlorophyta* (27% on average) at a depth of 192.53–196.88 m provides an evidence for a slight shallowing of the basin. It can be suggested that a slight decrease in water salinity occurred at that time, and the sedimentation took place in the shallow shelf zone. The assemblage from a depth of 192.23–198.23 m is labelled as K V.

Gonyaulacoid cysts (58%) are the most numerous phytoplankton components at a depth of 186.73 m. Less abundant are peridinioid cysts (16%) and *Prasinophyta* (8%). The percentage of freshwater (8%) and colonial (8%) *Chlorophyta* is slightly increased. No *acritarchs* have been found at this depth. A greater number of *Chlorophyta* specimens indicate the increasing significance of land-derived components. Freshwater phytoplankton was supplied to a outer-shelf basin by rivers. This interval of the section is labelled as K VI.

A slight shallowing of the basin is recorded in deposits from a depth of 183.18 m. The percentage of gonyaulacoid dinocysts decreased (45%). Inner shelf phytoplankton groups increased their contribution: *Prasinophyta* to 33%, and *Acrirarcha* to 18%, indicating higher-energy waters. Neither peridinioids nor continental phytoplankton have been found. This assemblage, characteristic of the inner shelf, is labelled as K VII.

The phytoplankton assemblage from a depth of 167.23 m proves a continuous shallowing of the basin and extending of the area of inner shelf facies. Gonyaulacoid dinocysts are less frequent (44%) and the amount of peridinioid cysts exceeds 33%. *Prasinophyta* (14%), *Acrirarcha* (4%) and colonial *Chlorophyta* (4%) are also present. This Lower Oligocene assemblage terminates the Paleogene marine sedimentary cycle from the Komorza 1/KB borehole, and is labelled as K VIII.

Łosiny 2/KB

The analysis of Middle Paleocene and Oligocene phytoplankton groups was performed on material from the Łosiny 2/KB borehole (Fig. 6). The depositional environment for sediments from a depth of 192.63 m can be defined as marine. Gonyaulacoid cysts (55%) and peridinioid cysts (29%) are dominant here. There are also *Acrirarcha* (6%), *Prasinophyta* (6%) and colonial *Chlorophyta* (3%), indicating marine deposition closer to the shoreline. The phytoplankton assemblage composition suggests conditions typical of the shallower zone of outer shelf. The local phytoplankton assemblage, labelled as L I, represents this part of the Paleocene section which is correlated with assemblage K III of the Komorza 1/KB section.

Upper in the section occur Lower Oligocene deposits containing at a depth of 190.43 m phytoplankton groups indicating the presence of nearshore facies. No gonyaulacoid dinocysts, being an indicator of deeper environments, occur here. Peridinioid cysts — typical of shallow-marine facies and cooler waters, *Acrirarcha* — showing the beginning of the transgressive cycle, and colonial *Chlorophyta* — living in lower salinity waters, occur in equal percentages — 33% each. This assemblage is characteristic of inner shelf facies and is labelled as L II.

Deposits from a depth of 182.68 m contain abundant gonyaulacoid dinocysts (50%) providing evidence for both deepening of the basin and normal salinity waters. No phytoplankton representatives of shallow nearshore zones have been found. The percentage of colonial and noncolonial freshwater *Chlorophyta* is still high (25% each). Such amounts of *Chlorophyta* occurring together with deeper marine taxa prove that the material was transported into a deeper zone of the basin, probably by rivers. This type of phytoplankton can indicate sedimentation close to deltaic deposition. The assemblage is labelled as L III.

At a depth of 176.33 m, there is a slight decrease in the percentage of gonyaulacoid cysts (41%). Instead, more appear absent previously peridinioid cysts (18%), *Prasinophyta* (12%) and *Acrirarcha* (6%) appear, indicating a shallowing of the basin. Colonial (12%) and noncolonial freshwater *Chlorophyta* (12%) are also present. The sedimentary environment became more freshwater and shallower. This assemblage is characteristic of the inner shelf and is labelled as L IV.

The phytoplankton assemblage identified at a depth of 165.58 m reflects a deepening of the sea. A considerable increase in the percentage of gonyaulacoid cysts (71%) and peridinioid cysts (23%) is observed. Also present are *Prasinophyta* (6%). There is a lack of both colonial and noncolonial freshwater *Chlorophyta*. This assemblage composition indicates the dominance of facies associated with areas more distant from the land. It also records the maximum extent of marine facies in this section and corresponds to the outer shelf zone. This assemblage is labelled as L V.

The Lower Oligocene phytoplankton assemblage from a depth of 161.18 m contains less gonyaulacoid cysts (55%) and peridinioid cysts (15%). Instead, the increased percentage of *Prasinophyta* (to 25%) is observed, indicating calm depositional conditions of a shallow-marine basin. Colonial *Chlorophyta* are relatively rare (5%). The basin became shallower, although its salinity remained unchanged. This phytoplankton assemblage is labelled as L VI.

Deposits from a depth of 144.78 m have yielded the Upper Oligocene phytoplankton assemblage containing no taxa which could indicate marine facies. Colonial and noncolonial freshwater *Chlorophyta* occur in equal amounts, showing that the sedimentation took place in a continental basin or in an isolated lagoon. This assemblage is labelled as L VII.

Phytoplankton identified at a depth of 144.13 m indicates a resumption of marine conditions, as evidenced by equal percentages of gonyaulacoid and peridinioid dinocysts (36% each). The presence of *Prasinophyta* (18%) and colonial *Chlorophyta* (9%) suggests rather a shallow marine basin of normal or slightly reduced salinity. This phytoplankton assem-

blage is labelled as L VII, and terminates the Paleogene sedimentary cycle in the Łosiny 2/KB section.

SEDIMENTATION AND PALAEOGEOGRAPHY OF PALEOGENE MARINE DEPOSITS FROM THE POMERANIAN LAKELAND

Some general regularities can be noticed when compare the succession of phytoplankton assemblages of Paleogene marine deposits in the two investigated sections (Fig. 6). The analysis of changes in composition of the phytoplankton assemblages, observed within the succession, shows that the Paleocene deposition took place under stable environmental conditions, in the deeper shelf, and with the absence elements of continental facies. Only minor sea-level changes manifested themselves at that time. In the lower part of the Komorza 1/KB section — assemblage K I, there is an episode of probable sedimentation in the outermost shelf. Upper in the section — assemblages K II and K IV — a slight shallowing of the continuously deep basin is recorded. There is the dominance of facies associated with the distal part of outer shelf, with only one fluctuation caused by a slight basin shallowing and accentuated by the appearance of assemblage K III. This part of the section can be correlated with assemblage L I of the Łosiny 2/KB section.

No Upper Eocene and Upper Eocene/Lower Oligocene deposits have been encountered in the Komorza 1/KB and Łosiny 2/KB sections, and the stratigraphic gap spans this interval. Palynologically dated Upper Eocene and Upper Eocene/Lower Oligocene deposits have been found in five other boreholes from the study area. The phytoplankton assemblage, identified in these boreholes, allowed the analysis of phytoplankton groups only to a limited extent. Upper Eocene deposits are probably represented in the Obrowo III borehole, where gonyaulacoid dinocysts and *Acrirarcha* representatives predominate. Such a phytoplankton composition allows to assign these deposits to outer shelf facies. Upper Eocene/Lower Oligocene transition deposits are known from the Kłodawa 4/KI, Kłodawa 5/KI, Mędromierz V and Kamień 2/Ka boreholes. These sediments contain a phytoplankton assemblage represented mostly by Dinoflagellata and *Acrirarcha*, with more or less equal percentages of peridinioid and gonyaulacoid dinocysts. It indicates a shallowing of the basin, dominance of inner shelf facies and normal salinity high-energy waters.

The contribution of individual phytoplankton groups in Oligocene deposits from the Komorza 1/KB and Łosiny 2/KB

boreholes is not so constant as in Paleocene sections. Changes in the phytoplankton composition allow to suggest that this was a high-energy marine environment. Facies are represented in general by more shallow marine ones than in the Paleocene. In the lower part of the Oligocene sedimentary cycle, there was a transgressive event, differently marked in each of the sections. In the Łosiny 2/KB section the transgressive phase is accentuated by dominant inner shelf facies (assemblage L II). In the Komorza 1/KB section the transgressive phase is recorded within outer shelf facies, when the sea already occupied a broader area (assemblage K V; Fig. 6). Therefore, it should be supposed that the sea transgressed from the north-west. The predominance of deltaic deposits (assemblage L III) is observed above the transgressive event in the Łosiny 2/KB section. Some analogous to this situation can also be recognized in the Komorza 1/KB section, where admixture of phytoplankton from continental facies, supplied to the marine basin by rivers, is noted within outer shelf deposits (assemblage K VI). It may indicate a minor regressive impulse. A sea-level drop and predominance of inner shelf facies, occasionally with continental deposits, is observed above in both the sections. Similar or corresponding sedimentary conditions, accentuated by a similar contribution of phytoplankton groups, are reflected in the presence of assemblages L IV, K VII and K VIII (Fig. 6). Upper part of the Oligocene sedimentary cycle are recorded only in the Łosiny 2/KB section. Assemblage L V reflects the maximum extent of the Early Oligocene sea. This episode manifested itself by a slight shallowing of the basin and higher contribution of shallow-marine facies, with no signs of continental influences (assemblage L VI — terminating the Lower Oligocene sedimentary cycle in this area).

Upper Oligocene deposits from the lower part of the Łosiny 2/KB section, represented by continental or lagoonal facies, accumulated in basins isolated from direct marine influences (assemblage L VII). In the latest Oligocene, a shallow sea inundated the area and inner shelf facies became dominant. Assemblage L VIII probably reflects an episode which can be interpreted as a regressive phase. Upper Oligocene deposits, containing assemblage L VIII (Fig. 6), terminate the marine sedimentation recorded in the Komorza 1/KB and Łosiny 2/KB sections.

Percentage contribution of phytoplankton groups in Lower and Upper Oligocene deposits from the remaining boreholes drilled in the study area is similar to that in the Komorza 1/KB and Łosiny 2/KB sections, where outer shelf dinocysts were predominant in the Lower Oligocene, and inner shelf dinocysts prevailed in the Upper Oligocene.

PALYNOFACIES ANALYSIS

SCOPE AND GOAL OF PALYNOFACIES STUDIES

Palynological macerates, obtained as a result of laboratory treatment, are composed most frequently of organic matter and a small amount of inorganic debris. Organic matter includes spores, pollen grains, phytoplankton, fungi spores and

sclerotia, foraminiferal linings, wood fragments (vessels, tracheids), cuticules (often with stomata), fragments of other tissues, and amorphous organic matter including resin and amber and other fragments of destroyed structure. Fragments of sponge spicules, individual glauconite grains, gypsum crystals and other components are also found. These constituents are objectives of investigations in the palynofacies analysis which

has been a rapidly developing method for the last twenty years (Manum, 1976; Manum, Thordsen, 1978; Durand, 1980; Batten, 1981, 1983; Baltes, 1984).

The essential goal of the palynofacies analysis is a reconstruction of sedimentary environments and depositional processes, as well as identification of transgressive-regressive cycles and sea-level changes. The analysis also provides information necessary to define the degree of alteration and maturity of deposits with regard to perspectives for hydrocarbon accumulations. Palynofacies investigations rely on a quantitative and qualitative analysis of palynological matter, and identification of the origin and physical features (shape, size and colour) of the studied components. In connection with the classical palynological analysis they provide a complete image of the ecological environment and sedimentary processes, resulting in the identification of characteristic features of a depositional succession for the sequence palynology (Prauss, 1993).

The term palynofacies was first introduced to the literature by Combaz (1964) and was used to define acid-resistant organic matter obtained using palynological maceration methods, and suitable for investigations in the light microscope. In this meaning the term palynofacies is similar to the term kerogen defined either as organic matter dispersed in a rock, insoluble in both organic and inorganic acids (Durand, 1980), or as organic residuum remaining after palynological extraction procedures, and being of size that allows light microscopic observations (Manum, 1983). Organic debris, dispersed in a deposit and represented mainly by algae, vascular plants and animal fragments, is called sedimentary organic matter (Clayton, 1994; Tyson, 1995; Batten 1996).

The term palynological organic matter was introduced in nineties during Organic Matter Workshop in Amsterdam to describe kerogen from modern and ancient deposits, observed in the transmitted light microscope. Batten (1996, 1999) introduced the term palynological matter for needs of the palynofacies analysis.

Palynological matter includes palynomorphs and palynoclasts (Fig. 7). Palynomorphs are represented by spores, pollen grains, fungi spores and sclerotia, phytoplankton — Acritarcha, Dinoflagellata, Prasinophyta, foraminiferal linings and other

taxonomically determinate microfossils that possess organic walls, insoluble in acids and possible to be isolated out by means of the density separation method (Tschudy, 1961). Palynoclasts can be defined as all dispersed structural and palynomorph-size amorphous organic debris e.g. wood fragments, cuticles, some of animal fragments and other structural and amorphous components of unknown biological origin. This term does not include taxonomically determinate components. Phytoclasts are represented by dispersed, frequently crumbled organic matter components limited to plant fragments, often with the original structure preserved (Bostick, 1971, 1974; Powell *et al.*, 1990).

The term palynofacies is also used to define a depositional environment. In this case, an assemblage of broadly comprehended organic matter (palynolithofacies, palynobiofacies) corresponds to a specific sedimentary environment. The term environmental palynofacies has a similar meaning including physical properties of plant material and the way of its transportation.

A scheme of division of palynological matter (PM) is shown below in the Fig. 7. A detailed classification of individual components of palynological matter is given in Słodkowska (in press).

COMPONENTS OF PALYNOLOGICAL MATTER IN THE ANALYSED MATERIAL

Palynomorphs

The primary objective of palynofacies studies are palynomorphs which are part of palynological matter that includes all organic small debris suitable for taxonomic identification. The presence and occurrence frequency of palynomorphs yields precise information on palynofacies, including the type of vegetation, climatic conditions, facies changes and palaeogeography.

Land plants debris are an autochthonous component in inland swamp basins. In both inland and open-marine basins, land plant fragments are mostly an allochthonous component. Phytoplankton of marine and freshwater basins is usually autochthonous.

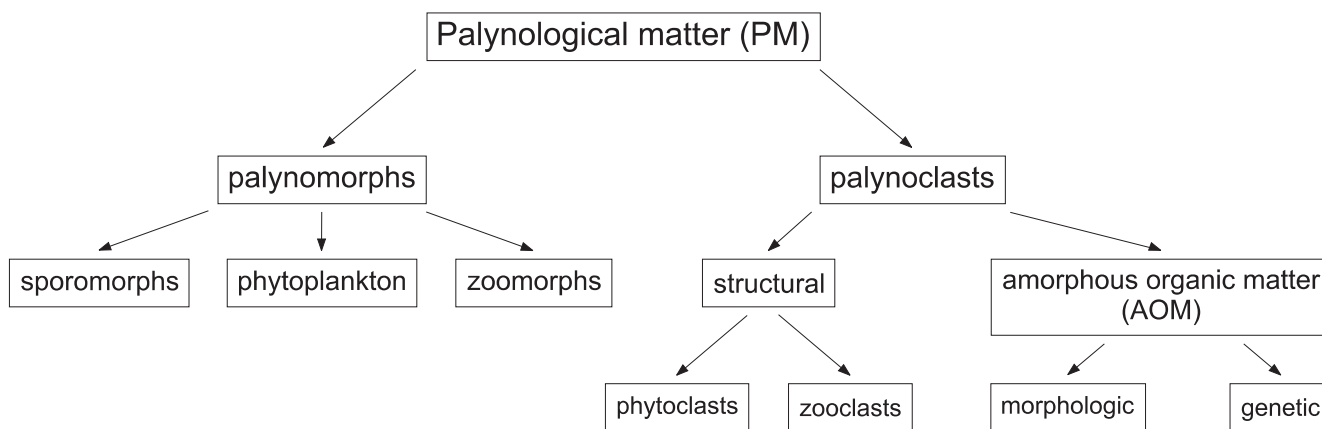


Fig. 7. Palynological matter classification

Palynomorphs in the studied material

Age	Palynomorphs	Environment
Upper Oligocene	marine phytoplankton << sporomorphs	Brackish
Lower Oligocene	marine phytoplankton < sporomorphs	Brackish
Upper Eocene/ Lower Oligocene	marine phytoplankton = sporomorphs	Brackish
Upper Eocene	marine phytoplankton > sporomorphs	Marine
Middle Paleocene	marine phytoplankton > sporomorphs, zoomorphs	Marine

The analysis of palynomorph composition allows to identify marine palynomorphs (phytoplankton and zoomorphs) and continental palynomorphs (sporomorphs, phytoplankton and zoomorphs). Such a division does not reflect the site of occurrence of palynomorphs within the depositional succession. For palaeo-geographic reconstructions, the analysis of proportions of marine to continental palynomorphs plays a significant role.

In the most of Middle Paleocene sections from the study area, marine phytoplankton considerably predominates over sporomorphs. Zoomorphs — chitinous foraminiferal linings, are also present (Table 5).

Marine phytoplankton predominates in Upper Eocene deposits; sporomorphs occur in lesser amounts. In the Upper Eocene/Lower Oligocene transition section, the proportion between marine and continental palynomorphs becomes equalized, suggesting a more near-shore depositional environment. In the Lower Oligocene these proportions change in favour of continental palynomorphs, indicating sedimentation in a shallow brackish basin. Upper Oligocene deposits contain considerably more continental palynomorphs and small amounts of marine ones.

Sporomorphs. Spores and pollen grains, transported into a sedimentary basin by winds and rivers, are more frequent in fine-grained deposits — silts and clays, and in organic deposits — in particular lignites. The occurrence or absence of spores and pollen grains in a basin depends on many factors. These are, among others, size and morphology of sporomorphs, maternal plants productivity, and soil and climatic conditions (Batten, 1996).

There is a regularity in the occurrence of individual sporomorph groups, associated with environmental factors, such as: water dynamics and distance from land. It causes sporomorphs, likewise phytoplankton, to be an important palaeoenvironmental indicator.

Two types of sedimentation can be observed when analysing the synthesis section of Paleogene deposits from the Pomeranian Lakeland: marine sedimentation in the lower part, followed by continental sedimentation. This obser-

Table 5

vation is also confirmed by the sporomorph composition identified in the analysed sections (Table 6).

In the Paleocene section dominate conifer pollen grains accompanied by small amounts of continental sporomorphs. It is characteristic of marine deposits. Bisaccate conifer pollen grains of low original gravity had the greatest chance to reach distant zones of the basin. A similar situation is observed in the Upper Eocene, where bisaccate pollen grains predominate. Other sporomorphs are rare in the spectrum. Bisaccate conifer pollen grains and spores were also supplied to the basin at the Late Eocene/Early Oligocene transition. Spores, in particular fern

spores, acquire significance in the Lower Oligocene deposits. Deciduous pollen grains are more frequent here, although the conifers predominate. The occurrence of small tricolporate pollen grains of mesophilous forest trees is distinctly accentuated. The proportions between various sporomorph groups, occurring together with abundant marine phytoplankton, indicate the shallow brackish sedimentary environment. The palynofacies image obtained for the Upper Oligocene is not so clear. The marine basin shows a regressive trend, and sporomorphs are not so frequent. Their poor state of preservation may indicate periodic uplifts and destruction of pollen material.

A separate sporomorph group is represented by fungal spores and sclerotia. The occurrence of fungal spores is associated with the presence of continental plants. Fungal spores are frequent in lacustrine and swamp environments, being an allochthonous component in marine and nearshore environments. They are abundant constituent of Paleogene assemblages.

Phytoplankton. Paleogene and Neogene phytoplankton of the study area is represented by specimens belonging to the algae divisions of Dinoflagellata, Prasinophyta, Chlorophyta and Acritarcha group. They provide much palaeoenvironmental information. The very most of the phytoplankton components occur *in situ*, unlike other organic debris.

A geographic range of modern Dinoflagellata is conditioned by quantity of sunlight, temperature, salinity, trophity and water dynamics (Batten, 1996). Similar factors must have influenced

Table 6**Sporomorphs in the studied material (Paleogene)**

Age	Sporomorphs	Environment
Upper Oligocene	Gymnosperms (saccate) = Angiosperms > Gymnosperms (nonsaccate), Spores	Brackish
Lower Oligocene	Gymnosperms (saccate + nonsaccate) = Angiosperms > Spores	Brackish
Upper Eocene/ Lower Oligocene	Gymnosperms (saccate) > Gymnosperms (nonsaccate) > Angiosperms, Spores	Brackish
Upper Eocene	Gymnosperms (saccate + nonsaccate) > Angiosperms, Spores	Marine — shelf
Middle Paleocene	Gymnosperms (saccate) > Angiosperms	Marine — shelf

the occurrence of these organisms in the past. Therefore, dinocysts and other phytoplankton groups are good environmental indicators.

Phytoplankton is distributed along the entire analysed section: marine phytoplankton occurs in Paleogene deposits, freshwater phytoplankton — in Neogene sediments (Table 7). The most common phytoplankton group in Paleogene deposits are Dinoflagellata. These include rich and diverse dinocyst assemblages characteristic of different marine sedimentary environments. For palynofacies considerations it was very important to identify the main dinocyst morphotypes (*proximate* and *chorate*) distinguishable by cell wall structure, by the occurrence or absence of processes on the cyst surface, and by the processes size (Sarjeant, 1982).

The problem of percentage contribution of individual phytoplankton groups in Paleogene deposits (Table 7) is widely discussed in the chapter entitled ‘Sedimentary conditions of Paleogene marine deposits reconstructed from phytoplankton’.

In all the Neogene deposits from the Pomeranian Lakeland, Chlorophyta freshwater phytoplankton is the most significant component. In sections containing coal beds, freshwater phytoplankton is also more abundant than in clastic ones (Table 7). The important feature of Neogene deposits from this area is lack of marine phytoplankton. It is occasionally observed as material redeposited from older sediments into Neogene deposits.

Table 7

Phytoplankton in the studied material

Age	Phytoplankton	Environment
Middle Miocene	Chun > Chm	Terrestrial — swamp
	Chun	Terrestrial — lake
Upper Oligocene	Chm, Chun, Dg, Dp, P	Brackish
Lower Oligocene	Dg >> Dp, P, A, Chm	Brackish
Upper Eocene/ Lower Oligocene	Dg, Dp, P	Brackish
Upper Eocene	Dg >> Dp, P	Marine — shelf
Middle Paleocene	Dg > Dp, P, A	Marine — shelf

Dg — Dinoflagellata gonyaulacoid cysts; Dp — Dinoflagellata peridinoïd cysts; P — Prasinophyta; A — Acritarcha; Chun — Chlorophyta unicellular; Chm — Chlorophyta multicellular

Zoomorphs, represented by organic foraminiferal linings, are frequent in Paleogene deposits of the area. These are usually juvenile cells of adult individuals. They occur in marine facies, in all types of lithologies ranging from clastics to carbonates. Modern foraminifers prefer warm and shallow waters, and therefore they have most often been noted in shelf deposits (Batten, 1996).

In the Komorza 1/KB borehole, foraminiferal linings are distributed within the entire Paleocene section, whereas in the Lower Oligocene section they occur only at the top. In

Table 8

Zoomorphs in the studied material

Age	Zoomorphs	Environment
Lower Oligocene	Foraminiferal linings	Brackish
Middle Paleocene	Foraminiferal linings	Marine — shelf

the Łosiny 2/KB borehole, they are observed in both Paleocene and Lower Oligocene deposits. Facies data, obtained from foraminiferal linings, generally correspond to those derived from the palynofacies analysis of phytoplankton (Table 8).

Palynoclasts

The analysis of palynoclasts primarily allows palaeogeographic interpretations, regarding mostly the distinguishing between continental and marine deposits, determination of distance from land, and palaeobathymetric considerations. It is also possible to identify the facies type. In the swamp environment the amount of plant matter (phytoclasts) is high. In the case of lack of any other organic components, data obtained from the palynoclast analysis enable a reconstruction of sedimentary conditions and, sometimes, correlation between deposits, as well as determination of age.

The palynoclast analysis with the zoomorph one, was performed on material from the Komorza 1/KB and Łosiny 2/KB boreholes (Figs. 8, 9). Some remarks were also given concerning the presence of mineral components such as individual glauconite grains and sponge spicules.

The results of the investigations should be treated as estimates, as the classification of organic matter from the samples is based on a two-degree scale 1 — single specimens, 2 — frequent specimens. The following types of palynoclasts have been identified: brown and black wood fragments, cuticles with stomata, amorphous organic matter and foraminiferal linings.

In the Komorza 1/KB (Fig. 8) section marine deposits can be clearly defined and separated from continental sediments. The lower part of the section (depth 203.21–248.50 m) contains only infrequent organic linings of the marine foraminifera and individual glauconite grains. Sponge spicules occur sporadically. Phytoclasts of continental plants are absent. It indicates a depositional site distant from the land. The upper part of the section (depth 167.23–198.22 m) contains palynoclasts that also provide evidence for marine sedimentation, although rare wood fragments and cuticles are noted in these deposits. Therefore, it was a more near-shore basin zone, into which continental plant fragments were supplied.

In the lower part of the Łosiny 2/KB (Fig. 9) section palynoclasts occur singly (depth 192.62 m). Also are present foraminiferal linings and individual glauconite grains, being an indicator of marine deposition, as well as black wood fragments and cuticles which indicate continental influence and transport of plant fragments from the land. More frequent fragments of continental plant tissues (phytoclasts) appear in marine deposits from a depth of 144.77–190.42 m, suggesting a close proximity to the land.

Komorza 1/KB Depth of samples (m)	167.23	183.18	186.73	192.53	196.88	198.23	203.22	208.78	211.73	212.78	213.18	214.68	220.00	231.50	239.50	245.30	248.50
Glauconite							1	1			1	1	1		1	1	
Foraminiferal linings	1						1	1	1	1	1	1	1		1	1	1
Amorphous organic matter																	
Cuticles and stomata	2	1	1	1	1	1											
Wood brown	1	1	1	1	1	1											
Wood black	1																
Chronostratigraphy	Lower Oligocene (Rupelian)						Middle Paleocene (Selandian)										

Fig. 8. Palynoclasts, zoomorphs and mineral debris in Paleogene deposits from Komorza 1/KB borehole

1 — single; 2 — frequent

Łosiny 2/KB Depth of samples (m)	144.12	144.77	161.17	165.57	176.32	182.67	190.42	192.62
Glauconite					1			1
Foraminiferal linings						1		1
Amorphous organic matter								1
Cuticles and stomata		2	2	1	1	2		1
Wood brown		2	2	1	1	2	1	1
Wood black								1
Chronostratigraphy	Upper Oligocene (Chattian)		Lower Oligocene (Rupelian)					Middle Paleocene (Selandian)

Fig. 9. Palynoclasts, zoomorphs and mineral debris in Paleogene deposits from Łosiny 2/KB borehole

1 — single; 2 — frequent

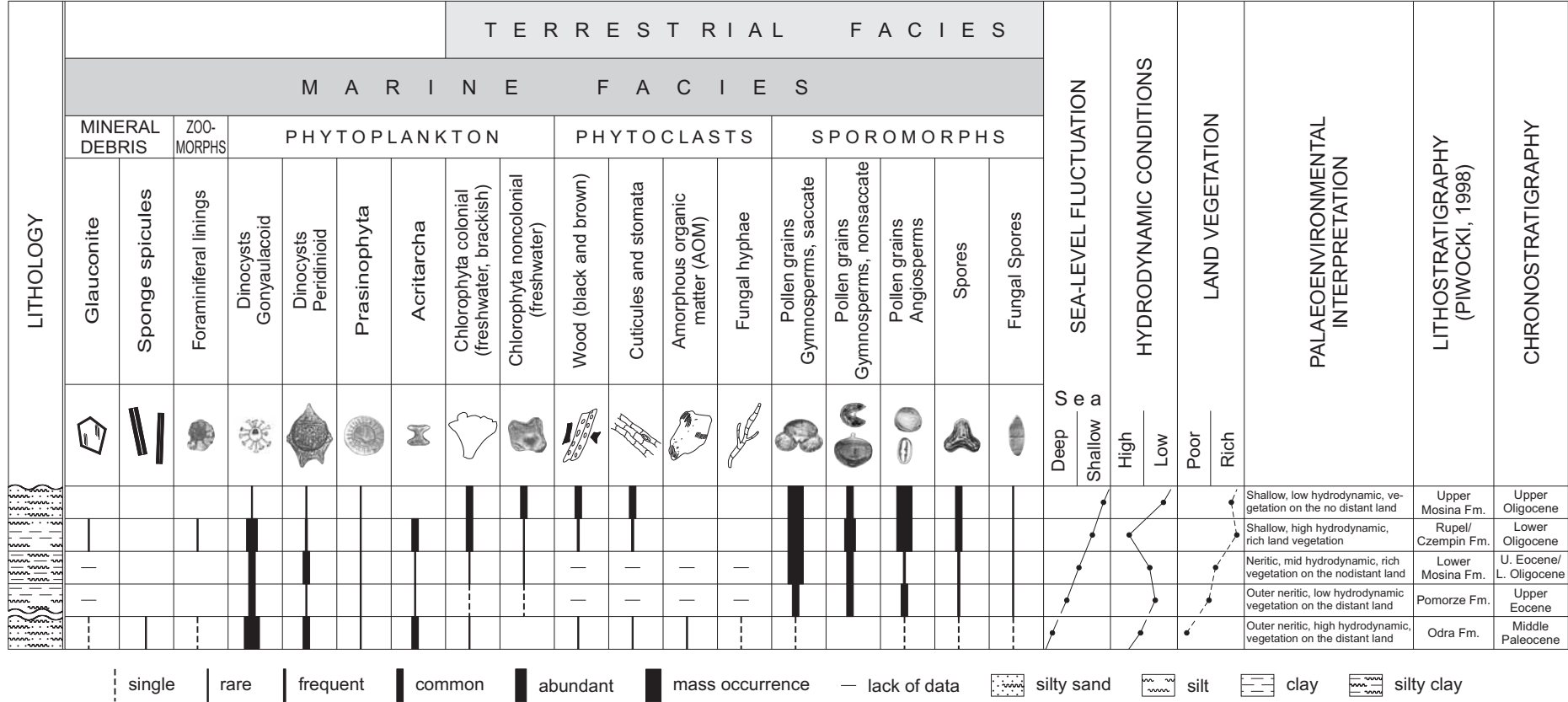
PALYNOLOGICAL MATTER IN THE SYNTHESIS SECTION OF PALEOGENE DEPOSITS

Data concerning palynological matter (PM) extracted from Paleogene deposits allow to construct a graph illustrating the contribution of palynomorphs and palynoclasts in a synthesis section of the Paleogene deposits from the Tuchola region (Fig. 10). In this graph, organic debris is grouped according to categories of palynological matter, and assigned to a specified facies of environments ranging from open-marine to continental. A six-degree scale of frequency of occurrence of palynological matter (reflecting an increasing number of palynomorphs and palynoclasts within individual assemblages) was used. Frequency of occurrence (single, rare, frequent, common, abundant, mass occurrence) is marked using lines of different thickness. These data, compared with sedimentary environments typical of individual types of palynological matter, allow to draw conclusions concerning Paleogene palaeoenvironments of the study area (Appendix A). It was the base for the reconstruction of sea-level changes, distant from land and water dynamics fluctuations within the basin.

Data obtained from continental vegetation are also partly recorded in marine facies. The amount of plant debris can indicate the distance between depositional site and the coastline. However, it says less about diversity of vegetation on land. The variety of palynological matter is also illustrated on photographic plates (Pls. XII–XIV).

Gonyaulacoid dinoflagellate cysts are the most significant components of phytoplankton material from Middle Paleocene silt-sand deposits. Peridinioid dinocysts and Acritarcha occur in lesser amounts. Prasinophyta and colonial Chlorophyta are rare. Phytoclasts, derived from the land, are also infrequent. Sporomorphs, including bisaccate pollen grains, occur singly. Zooclasts are represented by foraminiferal linings. There are also rare glauconite grains and individual sponge spicules. All the components identified in the Middle Paleocene deposits indicate the occurrence of deeper shelf facies. Furthermore, the high percentage of Acritarcha also provides evidence for high-energy waters. Plant fragments (sporomorphs and phytoclasts) were supplied to the basin only sporadically, indicating that depositional site were located far from the coastline (Pl. XII).

In Upper Eocene clay-silt deposits the occurrence of marine facies has been identified basing on the abundance of gonyau-



lacoid dinocysts and frequent peridinioid dinocysts. Prasino-phyta and Acritarcha are also represented in these deposits. Colonial Chlorophyta and freshwater noncolonial Chlorophyta appear sporadically. Of continental pollen grains, saccate conifer and angiosperm pollen grains are common. No phytoclasts have been found. Inferring from the occurrence of phytoplankton, it can be suggested that the deposition took place in a fairly deep-water basin, not far from the land.

The phytoplankton assemblages, identified in Eocene/Oligocene transition silt-clay deposits, indicate a shallowing of the basin. It is evidenced by the greater amount of peridinioid dinocysts and colonial and freshwater noncolonial Chlorophyta, with the continuously high percentage of gonyaulacoid dinocysts. The percentage contribution of saccate conifer pollen grains is higher, whereas deciduous pollen grains and spores are of little significance. No phytoclasts have been identified in this part of the section. The deposition occurred in rather a shallow-marine basin, far from the land, in a moderate-energy environment.

Lower Oligocene clay-silt deposits contain an abundant palynological matter assemblage. Marine facies are defined by the large percentage of phytoplankton with numerous gonyaulacoid dinocysts

and frequent peridinioid dinocysts. Abundant Acritarcha prove the occurrence of high-energy waters. Zooclasts are represented by foraminiferal linings. The presence of individual glauconite grains also indicates the marine environment. The land with luxuriant vegetation extended most probably not very far from the deposition site, as evidenced by the mass occurrence of various pollen grains, frequent and diverse spores, and high percentage of phytoclasts derived from the land. This palynological matter assemblage indicates a high-energy marine environment, its continuous shallowing, as well as decreasing distance from the coast (Pls. XIII, XIV).

Upper Oligocene silt-sand deposits contain less abundant phytoplankton. Dinoflagellata cysts are rare, colonial and freshwater noncolonial Chlorophyta are represented in larger amounts. Spermatophytes pollen grains occur en masse. Also abundant are spores and phytoclasts indicating luxuriant vegetation on the land, close to the shallow-marine basin. Phytoclasts are represented mostly by black and brown wood fragments and cuticles, frequently with stomata. This palynological matter assemblage provides evidence for a considerable shallowing of the basin, dominance of shallow-water facies, low-energy environment and proximity to the land (Pls. XIV).

PART II

POLLEN ANALYSIS OF PALEOGENE AND NEOGENE DEPOSITS

METHODOLOGY

GENERAL REMARKS

After using standard laboratory preparation methods of the studied sediments the numerous palynomorphs (spore-morphs, phytoplankton) and palynoclasts have been isolated. The pollen analysis method has been applied to spores and pollen. Their frequency and preservation state were satisfactory. Only in the part of the profile, which was related to the Paleocene, the frequency of the sporomorphs was low. In the pollen diagrams the presence of the specified taxa has been marked by a circle. Altogether, 343 taxa of the spores and pollen have been identified ([Appendix B](#)).

The determination of the sporomorphs was based on the morphological system (e.g. Thomson, Pflug, 1953, Krutzsch, 1962–1971); and also as far as it was possible the author used the natural plant systematics (Ziemińska-Tworzydło *et al.*, 1994a, b, Stuchlik *et al.*, 2001, 2002). While making the spore-pollen diagrams the author chose frequently occurring taxa and characteristic taxa having stratigraphical value, which occur rarely or scarcely in the pollen spectra. More often species belonging to one genus have been arranged into a separate column on the diagram. Particular genera and species of the fossil spores and pollen grains of the well-defined botanical affinity, have been grouped together considering the common habitat requirements, in compared them with the equivalents of the Recent plant communities ([Appendix B](#)). The plant communities selected in this way have been arranged in a line from the driest to the most humid. Such a data arrangement has enabled a separation of spore-pollen assemblages and definition of the dominant phases of the plant communities. These phases have been related to the appropriate relevant stratigraphical members.

The occurrence of the sporomorphs has been listed in [Appendix B](#) and the taxonomical names of the genera and species have been given with the creators' names, whereas in the study text, the full taxonomical names have not been used on the diagrams and on the graphs. The stratigraphical position of the spore-pollen spectra was based on the lithostratigraphical subdivision of the Neogene proposed by Piwocki and Ziemińska-Tworzydło (1995, 1997), Piwocki (1998), and GTS (2004).

Spore-pollen analyses have been applied to the marine Paleogene and terrestrial Neogene sediments. In the pollen analysis of the Paleogene deposits which are of marine or brackish origin, the composition of the pollen assemblages

show distinct differences. In the Paleocene and Eocene, prevail older 'Tertiary' taxa, among which the index and characteristic can be seen. However, in the Oligocene pollen are scarce. The Oligocene pollen flora has a transitional character between the floras of Paleogene and Neogene and therefore, the methodology applied to the pollen flora is more similar to the investigation methods used in the Neogene pollen floras.

INTERPRETATION THE POLLEN DATA IN THE NEOGENE

In the Neogene the spore-pollen spectra are more or less homogenous in respect of the species composition but the noticed quantitative differences between the assemblages are primarily connected with the climatic changes, especially with the occurrence of the more humid or dry periods. Berlie (1967) distinguished 27 taxa, which are permanently present in the Neogene assemblages. He also observed their quantitative changes in different periods, which enabled him to distinguish seven phases from Chattian to Pliocene. It was the first attempt to subdivide Neogene into palynological phases.

Krutzsch and Majewski (1967), for the sake of palynostratigraphical research, tried to define as characteristic those pollen taxa, which derived from entomophylous plants and occurring individually in the pollen spectra. This kind of pollen may serve as an indicator of the climate. Using this method, Krutzsch and Majewski (1967) established 13 climatic phases in Neogene.

Raniecka-Bobrowska (1970) concluded that in the Neogene plant communities, contained the same taxa, but due to changing of the environmental conditions different groups of sporomorphs became dominant. According to Raniecka-Bobrowska, an important role is played by those taxa, which are easy to define and occur in larger numbers. The method proposed by Raniecka-Bobrowska (1970) is similar to so called the method of index frequencies defined by Brellie (1967).

Ziemińska-Tworzydło (1974) established 13 pollen phases in the Neogene sediments of the western Poland and compared them with macrofloristical phases of Mai (1967).

In the palynostratigraphic subdivision of the Neogene, Sadowska in 1977 separated three groups of well-defined habitat requirement plants, in which spores and pollen are common in

the sediments. These are: 1 — plants of humid substratum without stratigraphical value; 2 — plants of temperate and warm-temperate climate; 3 — thermophilous plants. The analysis of the flora spectrum based on the proportion between the spores and pollen, enabled her to reconstruct the vegetative cover of south-western Poland.

Ziemińska-Tworzydło and Ważyńska (1981), on the basis of pollen spectra observation, isolated and named fourteen phases of plant changes during the Neogene in western Poland. These authors interpreted those changes as a result of the cyclic oscillation of the climate, which caused an alternate domination of the Palaeotropical and Arctotertiary elements. The authors also observed here a slight contribution of the tropical and subtropical elements to the warmer phases in the latest Miocene and Pliocene epochs. Kohlman-Adamska (1993) studied the ecological requirements of the plants defined on the basis of spores

and pollen. She grouped these taxa according to their habitat requirements and she also defined the following plant assemblages such as: mixed mesophilous forest, swamp forest, shrubby peat-bogs, sedge communities and aquatic plant assemblages. She attributed stratigraphical rank to the quantitative and qualitative changes of the plant taxa within the Neogene forest communities.

In a few papers (Piwocki, Ziemińska-Tworzydło, 1995, 1997; Ziemińska-Tworzydło, 1998), on the basis of analyses of numerous palynological profiles Ziemińska-Tworzydło again defined and modified 14 spore-pollen zones in Neogene, considering them as palaeoclimatic phases characteristic of the climatostratigraphy in Neogene.

In this study, the above presented methods have been compiled and flora climatic and palaeogeographic conditions in the pollen spectra of the Tuchola area sediments have been reconstructed.

RESULTS OF THE POLLEN ANALYSIS

The spore-pollen investigations of the Paleogene and Neogene sediments in the Pomeranian Lakeland have been carried out in twelve boreholes. The studied material derived from two densely sampled profiles of Komorza 1/KB (Fig. 11) and Łosiny 2/KB (Fig. 12), whereas the other profiles were more rarely sampled. Moreover, the author's studies have been extended by all accessible earlier palynological works done by other authors (Table 9). The detailed descriptions of the phytoplankton analyses have been quoted by the author in the same volume (see this paper, Part I).

Spore and pollen assemblages, which were characteristic of particular parts of the Neogene profile, were distinguished on the basis of the content of the pollen spectra. Changes in the composition of the flora in the two complete profiles of Komorza 1/KB and Łosiny 2/KB as well as in the supplementary profiles have been defined on the basis of the dominant plant communities. Their assignment was determined by such factors as: spectrum content analyses, quantitative proportions, ratio between the elements of the Arctotertiary and Palaeotropical geofloras A:P as well as by the assignment of particular taxa to the habitat assemblage. It was also possible to relate the flora assemblages described by the author to the palynological zones — climatic phases defined by Ziemińska-Tworzydło (1998). The isolated spore-pollen assemblages, which occur in the coal-bearing part of the profile, have been compared with the main lignite seam groups in Poland (Słodkowska, 1998a). The palynostratigraphical subdivision in the model profiles has been correlated with the other profiles (Table 10).

In all the studied profiles the taxa have been arranged according to a systematic order (spores, gymnosperm pollen and angiosperm pollen). Within each studied group the order of the quoted taxa depended on their occurrence in the profile. The taxa in the archival profiles were arranged in the different way such as: taxa of the angiosperm pollen, taxa of the gymnosperm pollen and the spores (Table 9). Within each group the succession depended on frequency of the occurrence in the assemblage. The index taxa have been underlined.

KOMORZA 1/KB

The Paleogene and Neogene sediments in the Komorza 1/KB borehole reached a thickness of 120 m. Lignite did not form thick seams; for example, the thickness in the five seams reached up to 2.5 m. The investigations were carried out in coaly and silty sediments. The palynological analyses distinguished seven assemblages — phases characterized by the dominant plant communities (Fig. 11; Table 10). Within the Paleogene sediments it was possible to distinguish two phases while in Neogene up to five.

The oldest palynologically dated sporomorph assemblage has been selected from the silty and glauconitic sands as well as from the marly limestones out of the depth of 203.20–248.50 m. In this assemblage a single, badly preserved and corroded pollen grains, which mainly derived from the Upper Cretaceous–Lower Paleogene Normapolles group, have been found. The following taxa have been identified: *Interpollis*, *Longanulipollis* cf. *capsula*, *Nudopollis endangulatus*, *N. thiergarti*, *Semioculopollis*, *Trudopollis* and *T. cf. bulboformis*. The age of this profile was established thanks to the presence of characteristic phytoplankton assemblage as well of the Normapolles pollen as dating from the Middle Paleocene — Selandian.

The next assemblage was found in the overlying sandy silts at the depth of 167.21–198.25 m. In comparison with the previous one the main features of this assemblage were: a high frequency of spores, and the pollen grains but a slightly smaller share of phytoplankton. The gymnosperm plants were represented by a pollen of the following plants: *Pinuspollenites* — up to 22%, *Sequoiapollenites* — up to 8.5%, *Inaperturopollenites dubius* — up to 11.0%, *I. hiatus* — up to 6.0%, *Sciadopityspollenites* — up to 4.0%, and *Cupressacites bockwitzensis*, other taxa have not been so numerous. Among the angiosperm pollen the permanent and abundantly occurring elements were such as: *Castaneoideaepollis pusillus* — up to 18.0%, *C. oviformis* 4.0% and *Fususpollenites fusus* — up to

Table 9

Results of the spore-pollen studies other authors¹

Borehole author, year	Depth of distinguished assemblages	Characteristic taxa	Age, Plant communities phases	Lithostratigraphy, spore-pollen zones
Kłodawa 4/K1 Ważyńska, 1987b	245.00–270.50	<i>Fususpollenites fusus</i> , <i>Castaneoideaepollis oviformis</i> , <i>C. pusillus</i> , <i>Tricolporopollenites fallax</i> , <i>T. megaexactus</i> , <i>T. liblarensis</i> , <i>T. retiformis</i> , <i>Oligopollis pentaporis</i> , <i>Aglaoreidia cyclops</i> , <i>Boehlensipollis hohli</i> , <i>Cupanieidites eucalyptoides</i> , <i>Cicatricosisporites paradorogensis</i> , <i>Verrucatosporites megabalticus</i>	Lower Oligocene, D	Czempin Formation
	274.00	<i>Tricolporopollenites megaexactus</i> , <i>Castaneoideaepollis oviformis</i> , <i>Platanipollis ipelensis</i> , <i>Tricolporopollenites retiformis</i> , <i>Inaperturopollenites</i> , <i>Cupressacites</i> , <i>Pinuspollenites</i> , <i>Sciadopityspollenites</i>	Upper Eocene/ Lower Oligocene, C	Lower Mosina Formation
Kłodawa 5/K1 Ważyńska, 1987a	178.50–225.20	<i>Fususpollenites fusus</i> , <i>Tricolporopollenites exactus</i> , <i>Quercoidites henrici</i> , <i>Engelhardtioipollenites punctatus</i> , <i>E. quietus</i> , <i>Castaneoideaepollis pusillus</i> , <i>C. oviformis</i> , <i>Platanipollis ipelensis</i> , <i>Tricolporopollenites megaexactus</i> , <i>T. liblarensis</i> , <i>T. fallax</i> , <i>Milfordia incerta</i> , <i>Juglandipollis maculosus</i> , <i>Aglaoreidia cyclops</i> , <i>Boehlensipollis hohli</i> , <i>Cupanieidites eucalyptoides</i> , <i>Reevesiapollis major</i> , <i>Dicolporopollis kockeli</i> , <i>Dicolporopollenites middendorfi</i> , <i>Inaperturopollenites</i> , <i>Cupressacites</i> , <i>Sequoiapollenites</i> , <i>Cicatricosisporites dorogensis</i> , <i>C. paradorogensis</i> , <i>Camarozonosporites heskemensis</i>	Lower Oligocene, D	Czempin Formation
	242.70–242.80	<i>Tricolporopollenites exactus</i> , <i>Engelhardtioipollenites punctatus</i> , <i>E. quietus</i> , <i>Fususpollenites fusus</i> , <i>Castaneoideaepollis pusillus</i> , <i>C. oviformis</i> , <i>Tricolporopollenites retiformis</i> , <i>Inaperturopollenites</i> , <i>Cupressacites</i> , <i>Pinuspollenites</i> , <i>Sciadopityspollenites</i>	Upper Eocene/ Lower Oligocene, C	Lower Mosina Formation
Myśligoszcz 1 Mamczar, 1963	213.40–231.50	<i>Betulaepollenites</i> , <i>Alnipollenites</i> , <i>Nyssapollenites</i> , <i>Arecipites</i> , <i>Fususpollenites fusus</i> , <i>Inaperturopollenites</i> , <i>Cupressacites</i> , <i>Pinuspollenites</i> , <i>Piceapollis</i> , <i>Podocarpidites</i>	Lower Oligocene, D	Czempin Formation
	245.70–250.00	<i>Gleicheniidites</i> , lack of angiosperms	Lower Cretaceous	
Gronowo 2 Mamczar, 1963	242.90–249.40	<i>Tricolporopollenites pseudocingulum</i> , <i>Quercoidites</i> , <i>Fususpollenites fusus</i>	Lower Oligocene, D	Czempin Formation
	252.00–256.60	<i>Concavisporites punctatus</i> , <i>Cingulatisporites valdensis</i> , <i>Lygodium giberrulum</i> , <i>Gleicheniidites</i>	Lower Cretaceous	
Gronowo 3 Mamczar, 1963	236.00–241.00	<i>Fususpollenites fusus</i> , <i>Myricipites</i> , <i>Betulaepollenites</i> , <i>Engelhardtioipollenites</i>	Lower Oligocene, D	Czempin Formation
	245.00	<i>Cingulispors valdensis</i> , <i>Coniopteris</i> , <i>Cheirolepidaceae</i> , <i>Gleicheniaceae</i>	Lower Cretaceous	
Lyskowo PG 1 Rębas, 1984	11.50–12.00	<i>Tricolporopollenites megaexactus</i> , <i>T. exactus</i> , <i>Ilexpollenites</i> , <i>Ericipites</i> , <i>Pinuspollenites</i> , <i>Sciadopityspollenites</i>	Middle Miocene, H	Pawłowice/Adamów Formation VI <i>Tricolporopollenites megaexactus</i>
	29.00–29.50	<i>Quercoidites henrici</i> , <i>Tricolporopollenites pseudocingulum</i> , <i>T. exactus</i> , <i>Engelhardtioipollenites</i> , <i>Nyssapollenites</i> , <i>Tricolporopollenites megaexactus</i>	Middle Miocene, F/G	Ścinawa/Krajenka Formation II Łużyce Lignite Seams V <i>Quercoidites henrici</i>
	30.60–47.70	<i>Inaperturopollenites</i> , <i>Cupressacites</i> , <i>Sequoiapollenites</i> , <i>Pinuspollenites</i> , angiosperms to 1 %	Miocene undivided	
	70.40–170.20	<i>Fususpollenites fusus</i> , <i>Castaneoideaepollis pusillus</i> , <i>Quercoidites microhenrici</i> , <i>Engelhardtioipollenites punctatus</i> , <i>Boehlensipollis hohli</i> , <i>Cupanieidites eucalyptoides</i>	Lower Oligocene, D	Czempin Formation
Wilcze IG 1 Grabowska, 1985	145.00–175.00	<i>Boehlensipollis hohli</i> , <i>Cupanieidites eucalyptoides</i> , <i>Dicolporopollenites middendorfi</i> , <i>Milfordia incerta</i> , <i>Juglandipollis maculosus</i> , <i>Tripoporopollenites megagraniifer</i> , <i>Camarozonosporites heskemensis</i> , <i>Cicatricosisporites dorogensis</i>	Lower Oligocene, D	Czempin Formation
	190.00–215.00	<i>Gleicheniidites</i> , lack of angiosperms	Lower Cretaceous	

¹ All archival elaborates were analysed in details and then revised and the phases of the plant communities have been defined by author

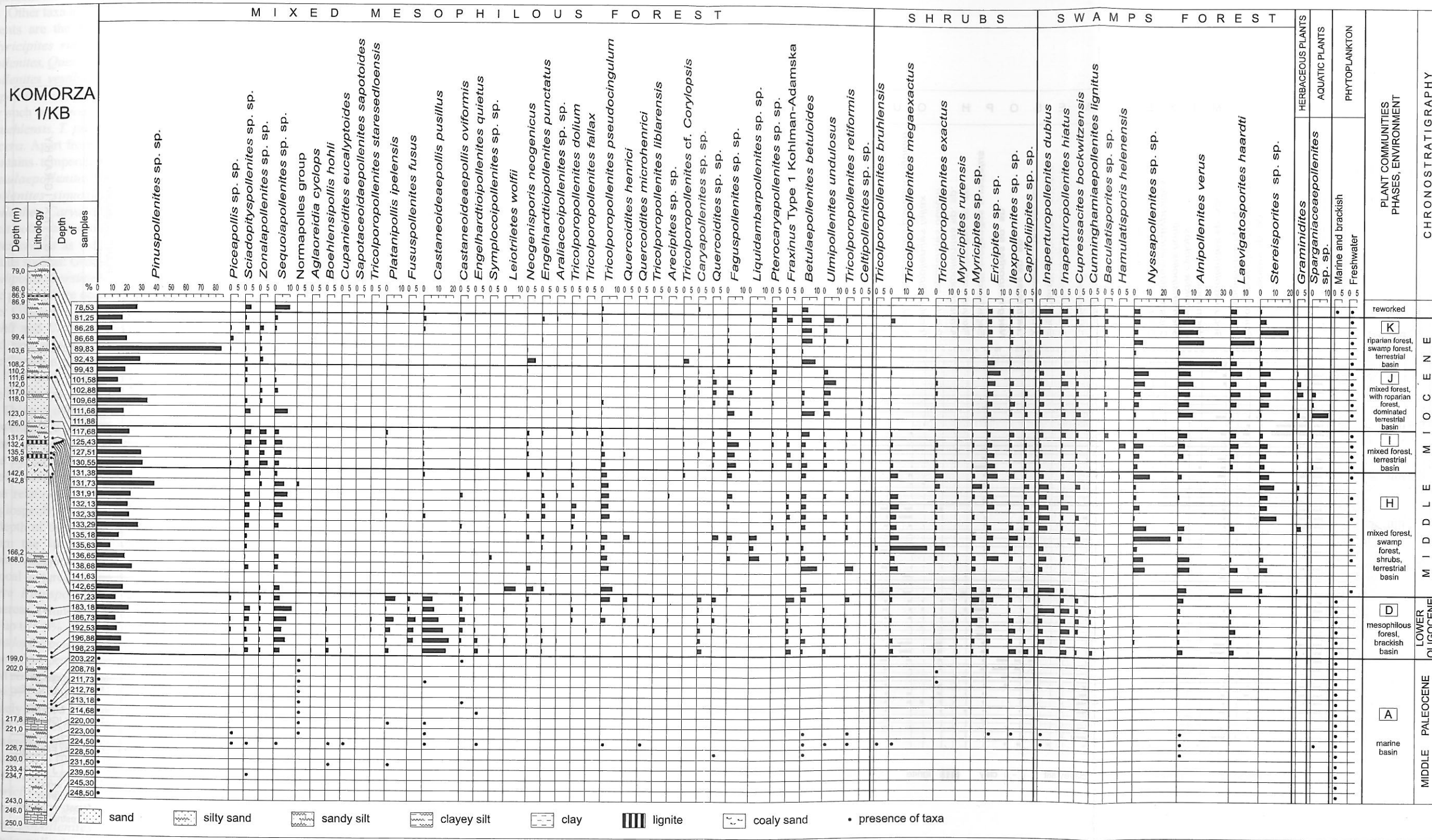


Fig. 11. Pollen diagram of Komorza 1/KB borehole

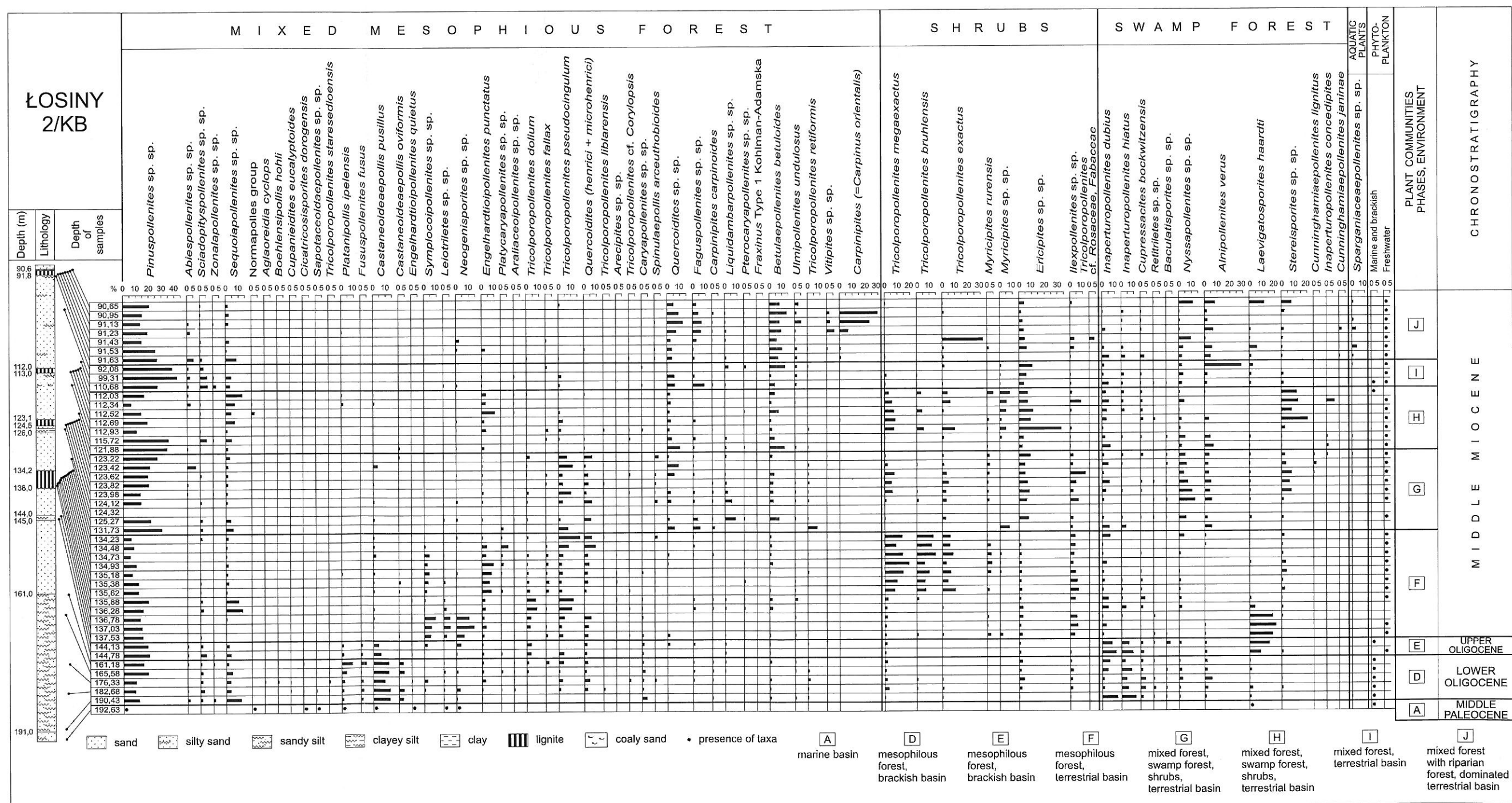


Fig. 12. Pollen diagram of Łosiny 2/KB borehole

5.5%. These small tricorporate grains are more often related to the Castaneoideae subfamily of the Fagaceae family and they represent the Palaeotropical geoflora element.

Other taxa in the studied spectra of higher thermal requirements are the following: *Engelhardtioipollenites quietus*, *Myricipites rurensis*, *Platanipollis ipelensis*, *Platycarya-pollenites*, *Quercoidites henrici*, *Q. microhenrici*, *Symplocarpipollenites vestibulum*, *S. orbis* and *Sapotaceoidaepollenites sapotoides* as well as the pollen of an unknown botanical affinity such as: *Tricolporopollenites megaexactus*, *T. exactus*, *T. bruehlensis*, *T. pseudocingulum*, *T. staresedloensis*, *Milfordia incera*. Apart from the warmth-loving elements the spectrum contains temperate elements such as: *Alnipollenites verus*, *Betulaepollenites betuloides*, *Faguspollenites*, *Tricolporopollenites sinuosimuratus*, *Pterocaryapollenites*, *Nyssapollenites*, *Caryapollenites simplex*, *Carpinipites carpinoides*, *Celtipollenites verus*, *Aceripollenites*, *Ilexpollenites*, *Ericipites ericius* as well as not numerous pollen of herbaceous plants such as: *Graminidites*, *Sparganiaceapollenites*, *Chenopodipollis*, *Corsinipollenites* occurred. In the discussed part of the profile there occurred index taxa characteristic of the Lower Oligocene such as: *Aglaoeidia cyclops*, *Boehlensipollis hohli* and *Cupanieidites eucalyptoides*. The above presented assemblage is characteristic of the Lower Oligocene in the Czempin Formation.

The next, analysed part of the profile was derived from the lignite and coaly sand deposits at a depth of 131.35–142.70 m. This part of the section is separated from the previous one by a twenty-five metre complex of sandy deposits. The spore assemblage of this part of the section differs from the previous one by the lack of marine phytoplankton. The frequency of the sporomorphs and the species differentiation level was low. The relationship between the quantity of gymnosperm and angiosperm pollen was almost the same. In the sediments at a depth of the 135.60–135.65 m a bigger presence of spores from the species of *Neogenisporis* cf. *plicatoides* and *Concavisporites* fsp. 4, was observed which should be seen as a local feature. Among the gymnosperms the dominant pollen were *Pinuspollenites*, which amounted to 25.0–40.0%, whereas gymnosperm plant pollen such as *Sequoiapollenites* — up to 9.0%, *Inaperturopollenites dubius* — up to 7.0% and *Sciadopityspollenites* — up to 3.0% occurred less frequently. The angiosperm pollen were more taxonomically differentiated consisting of: *Tricolporopollenites pseudocingulum* — up to 6.0%, *T. exactus* — up to 7.0%, *T. megaexactus* approximately about 6.0%, with a maximum content in one sample up to 25.0%. Besides, *T. bruehlensis*, *T. dolium*, *T. retiformis* — occurred sporadically, and different species of *Nyssapollenites* amounted to 10.0–28.0%, *Liquidambarpollenites stigmatus* — up to 7.0%, *Ericipites ericius* — up to 6.0%, *Quercoidites henrici* — up to 4.0% while such taxa as: *Platanipollis ipelensis*, *Myricipites rurensis*, *M. bituitus*, *M. coryphaeus*, *Tricolporopollenites sinuosimuratus*, *Alnipollenites verus*, *Betulaepollenites betuloides*, *Faguspollenites* and *Carpinipites carpinoides* occurred in a smaller amounts. At a depth of 131.70–131.75 m, pollen grains from the Normapollis group have been identified, which probably derived from reworked deposits, since there were no other Paleogene taxa.

The above described spore-pollen assemblage with a distinctive part of warmth-loving species and representatives of shrubs were deposited in a freshwater basin. It may be related to the IIA Lubin Lignite Seam and to the corresponding **VI Tricolporopollenites megaexactus** spore-pollen Zone in the Middle Miocene Pałowice/Adamów Formation. The lithological change in this profile is clearly reflected in the contents of the spectrum. In the coaly parts of the profile there is an increased number of pollen coming from the swamp forest plants and brushwood.

The next pollen assemblage at a depth of 117.65–130.59 m was isolated from the sandy-silts, above the series of coaly deposits. The frequency of the sporomorphs and the differentiation on the species level were higher than in the previous part of the profile. The mosses and ferns were here scarcely represented, showing a high taxonomical differentiation. The ratio between the gymnosperm and angiosperm pollen plants was more or less equal. Among the gymnosperms the most numerous were *Pinuspollenites* — up to 31.0%, less common *Sequoiapollenites* — approximately about 5.0% and *Sciadopityspollenites* — up to 4.5%. For the first time the share of a different species, the *Zonalapollenites* was constant and amounted to 5.0%. The pollen of the angiosperms were more differentiated taxonomically; e.g. among the taxa occurred *Faguspollenites* — up to 8.0%, *Nyssapollenites* — up to 7.0%, *Betulaepollenites betuloides* — up to 5.5%, *Alnipollenites verus* — up to 5.0%, *Ericipites ericius* — approximately about 5%, *Ulmipollenites undulosus*, *Quercoidites* and *Tricolporopollenites sinuosimuratus*. Besides, there was a small amount of pollen of warmth-loving plants such as: *Tricolporopollenites pseudocingulum* — up to 2.5%, *T. megaexactus*, *T. dolium*, *Platanipollis ipelensis*, *Engelhardtioipollenites punctatus*, *Castaneoideaepollis pusillus*, *C. oviformis* and *Spinulaepollis arceuthobioides*. However, a warm-temperate Arctotertiary element was prevalent. Considering the composition of all the spectrum elements, the profile part of the **VII Iteapollis angustiporatus** Zone can be correlated with the Middle Miocene Pałowice/Adamów Formation. In the above studied assemblage the index taxon has not been noted, as according to the definition of the *Iteapollis angustiporatus* Zone, the share of the index taxon hardly reaches 1% (see Ziemińska-Tworzydło, 1998).

The successive assemblage has been distinguished in the lignite deposits and in the overlying sandy-silts at the depth of the 99.45–111.90 m. The spores and the pollen grains here were quite numerous and well preserved. Particularly, the spores were taxonomically differentiated, but were not significant in quantity. Among the gymnosperms the most common was *Pinuspollenites* which reached up to 15.0–34.0%, but less common were the following taxa: *Sequoiapollenites* — approximately about 2.0%, *Inaperturopollenites dubius* and *Cupressacites bockwitzensis* as well as species of *Zonalapollenites* genus which reached up to 2.0–3.5% and occurred regularly. The plants of the angiosperms had a slightly bigger share in this assemblage, but the most common was the temperate element of the Arctotertiary geoflora such as: *Alnipollenites verus* — 17.0–29.0%, *Nyssapollenites* — up to 11.0%, *Betulaepollenites betuloides* — up to 9.0%, *Ulmipollenites*

undulosus — up to 8.0%, *Eriopites ericius* — up to 8.0%, *Quercoidites* — up to 7.0%, *Pterocaryapollenites* — up to 3.0%, *Celtipollenites verus* — 1.2% and *Caryapollenites simplex*. The herbaceous plants were represented by: *Sparganiaceapollenites sparganioides*, *Graminidites*, *Myriophyllumpollenites*, *Corsiniipollenites*, *Cichoraecidites gracilis*, *Tubulifloridites* and *Trapapollis*. The warmth-loving taxa were scarce and the following species had been noted: *Tricolporopollenites pseudocingulum*, *T. exactus*, *T. dolium*, *Liriodendroipollis verrucatus*, *Myricipites microcoryphaeus*, *Castaneoideaepollis pusillus*, *C. oviformis*, *Spinulaepollis arceuthobioides* and *Araliaceipollenites edmundi*. The above-mentioned warmth-loving taxa formed only an additional part of this assemblage, which was dominated by the temperate element. In this assemblage a freshwater phytoplankton was also observed. A remarkable fact was the abundant occurrence of freshwater Dinoflagellata, which are usually rarely seen in the Miocene sediments.

The above presented sporomorph assemblage reflects a stage in the development of plants which have bigger requirements of substratum humidity. The composition of this assemblage, in spite of the low share of the index taxon which gave the name to this zone, may be correlated with the **VIII** *Celtipollenites verus* Zone, which defined the I Middle Polish Lignite Seam in the Middle Miocene.

The overlying part of the profile at the depth of the 81.00–92.45 m are separated from the lower part of the profile by a sand layer of 6 m thick. The sandy silt sequences containing a thin layer of lignite were analysed. The distinguished assemblage was characterized by a rather high frequency of sporomorphs; their taxonomical differentiation was also smaller than in the deeper part of the sediments. The spores were not numerous but were a stable element of the spectrum. The gymnosperm plants were represented by the *Pinuspollenites* — approximately about 30.0%, but at the depth of 89.80–89.85 m *Pinuspollenites* occurred abundantly which reached 84.0%. In a small quantity up to maximum of 4.0%, there could be found: *Sciadopityspollenites*, *Inaperturopollenites dubius*, *I. hiatus*, and different species of *Zonapollenites* and *Sequoiapollenites*. Among the angiosperms dominated: *Alnipollenites verus* which reached up 10.0–15.0%, (with a maximum of 30.0%), *Betulaepollenites betuloides* which ranged between 7.0–10.0%, *Ulmipollenites undulosus* — up to 6.0%, *Nyssapollenites* — up to 5.0% and in small quantities occurred: *Quercoidites*, *Pterocaryapollenites* and *Caryapollenites simplex*, which formed pollen grains of the Arctotertiary geoflora. Also, a small quantity of herbaceous and aquatic plants such as *Persicarioipollis*, *Umbelliferoipollenites*, *Cichoraecidites gracilis*, *Tubulifloridites*, *Caryophyllidites rueterbergensis*, *Sparganiaceapollenites*, *Pseudotyphoipollis punctiporatus*, *Butomuspollenites* and *Nupharipollenites kedvesii* has been noted. There occurred an insignificant amount of the pollen of the Palaeotropical geoflora such as: *Tricolporopollenites pseudocingulum*, *T. megaexactus*, *T. exactus*, *Araliaceipollenites euphori*, *Myricipites rurensis*, *Castaneoideaepollis pusillus*, *C. oviformis*, *Spinulaepollis arceuthobioides*, *Engelhardtioipollenites punctatus*, *Quercoidites henrici* and *Myricipites*

microcoryphaeus. Freshwater phytoplankton was not numerous and differentiated. Separate specimens of marine phytoplankton, which was found on the reworked deposits, were also noted. The composition of the above presented assemblage with a surplus of cool temperate taxa was related to the content of the pollen spectra from the Middle Miocene IA Oczkowice Lignite Seam, represented by the **IX** spore-pollen *Tricolporopollenites pseudocingulum* Zone, although the species which gave the name to this zone rarely occurs in the pollen spectra of the above discussed assemblage.

ŁOSINY 2/KB

The Paleogene and Neogene sediments in the Łosiny 2/KB profile reached a thickness of about 100 metres. Lignite sediments formed moderately thick seams, of a total thickness of 7.2 m, where the thickest seam reached up to 3.8 m. The pollen analyses were carried out in coal-bearing and silty series of the sediments.

The undertaken investigations distinguished seven spore-pollen assemblages, which were different in composition and character (see Fig. 12; Table 10). In the Paleogene sediments was possible to distinguished three assemblages while in Neogene series up to five spore-pollen assemblages. The oldest palynologically dated assemblage has been selected from silty-sands at a depth of 192.60–192.65 m. In spite of a low frequency of sporomorphs and a great taxonomical differentiation in the composition of this assemblage the following spores have been recognized e.g. *Camarozonosporites heskemensis*, *Cicatricosisporites dorogensis*, *Leiotriletes maxoides*, *L. minor* and *Corrugatosporites* as well as others. The occurrence of the *Classopollis* pollen, which represent mesophilous gymnosperm plants, deserves a special attention. Among the angiosperms occurred such taxa as: *Sapotaceoideaepollenites*, *Subtriporopollenites anulatus*, *Platanipollis ipelensis*, *Engelhardtioipollenites quietus*, and *Castaneoideaepollis pusillus*. The representatives of the Normapolles group such as *Extratriporopollenites parmatius*, *Nudopollis thiergartii*, *N. minutus*, *Oculopollis concentus* and *Vacuopollis semiconcavus* have also been noted. The age of this part of the profile was established thanks to the presence of abundant phytoplankton as well as mainly on the basis of Normapolles pollen dating from the Middle Paleocene — Selandian. The next spore-pollen phytoplankton assemblage has been found in silty-sand deposits at a depth of 161.15–190.45 m. The frequency of the sporomorphs was high and preservation state of pollen was satisfactory. The spores were not numerous, but taxonomically differentiated and the following taxa have been identified: *Neogenisporis neogenicus*, *Verrucatosporites alienus*, *Baculatisporites primarius*, *B. nanus*, *B. quintus*, *Toroisporis*, *Camarozonosporites heskemensis*, *Cicatricosisporites dorogensis*, *Radialisporis radiatus*, *Leiotriletes wolfii*, *Echinatisporis embryonalis*, *E. cf. cycloides*, *Cryptogrammasporis*, *Retitriletes flaemingensis* and *Triplanosporites microsinosus*. The relationship between the quantity of gymnosperm and angiosperm pollen was more or less the same. Among the abun-

Table 10

Phases of plant communities and their stratigraphical position in the Tuchola region profiles

Plant communities phases	Komorza 1/KB	Łosiny 2/KB	Raciąż II	Tuchola-Białowieża VI	Wymysłowo XI	Obrowo III	Mędromierz V	Jeleń IV	Kamień 2/Ka	Piła Młyn V	Gostycyn Iv	Lisie Jamy X	Kłodawa 4/Kł	Kłodawa 5/Kł	Mysłogoszcz 1	Gronowo 2	Gronowo 3	Łyskowo PG 1	Wilcze IG 1	Climatic phases — spore-pollen zones (Ziemińska-Tworzydło, 1998), Dinoflagellate zones (Powell, 1992)	Litostratigraphy (Piwocki, 1998)	Lignite Seams	Chronostratigraphy
K	+						+			+										IX <i>Tricolporopollenites pseudocingulum</i>	Poznań Formation	IA Oczkowice	Middle Miocene
J	+	+						+			+									VIII <i>Celtipollenites verus</i>	Poznań Formation	I Middle Polish	Middle Miocene
I	+	+																		VII <i>Iteapollis angustiporatus</i>	Pawłowie/Adamów Formation		Middle Miocene
H	+	+	+			+		+		+								+		VI <i>Tricolporopollenites megaexactus</i>	Pawłowie/Adamów Formation	IIA Lubin	Middle Miocene
G		+																		V <i>Quercoidites henrici</i>	Ścinawa/Krajenka Formation	II Łużyce	Middle Miocene
F/G										+		+						+		V <i>Quercoidites henrici</i>	Ścinawa/Krajenka Formation	II Łużyce	Middle Miocene
F		+		+	+				+		+									V <i>Quercoidites henrici</i>	Ścinawa/Krajenka Formation	II Łużyce	Middle Miocene
E		+					+													D14/D15	Upper Mosina Formation		Upper Oligocene (Chattian)
D	+	+	+	+	+	+		+	+	+	+		+	+	+	+	+	+	+	D14	Czempin Formation		Lower Oligocene (Rupelian)
C							+		+				+	+						D12/D13	Lower Mosina Formation		Upper Eocene/ Lower Oligocene
B						+														D12	Pomorze Formation		Upper Eocene
A	+	+																		D3-D4	Odra Formation		Middle Paleocene Selandian

*reverse stratigraphical sequence

dantly occurring gymnosperms the following taxa have been identified: *Pinuspollenites* — up to 20.5%, *Inaperturopollenites dubius* — up to 10.8%, *I. hiatus* — up to 9.1%, *Sciadopityspollenites* — up to 9.5%, *Sequoiapollenites* — up to 3.7%, *Cupressacites bockwitzensis* — up to 2.4% as well as others. The angiosperms taxa were represented by the Palaeotropical elements consisting of: *Castaneoideaepollis pusillus* — up to 13.0%, *Fususpollenites fusus* — up to 4.5%, *Castaneoideaepollis oviformis* — up to 4.1%, *T. megaexactus* — 3.3%, *Quercoidites henrici* — up to 2.9% as well as: *Q. microhenrici*, *Tricolporopollenites dolium*, *T. exactus*, *T. starresedloensis*, *T. eofagoides*, *T. oleoides*, *Triplopollenites palaeobetuloides*, *Platanipollis ipelensis*, *Symplocoipollenites latiporis*, *S. orbis*, *S. vestibulum*, *Sapotaceoideaepollenites oblongus*, *S. sapotoides*, *Platycaryapollenites*, *Engelhardtioipollenites quietus*, *Araliaceoipollenites euphori*, *A. reticuloides* and others. In the spectrum were also present the index Lower Oligocene species such as: *Aglaoreidia cyclops*, *Boehlensipollis hohli*, and *Cupanieidites eucalyptoides*. Rich marine phytoplankton formed a supplementary part of the spectrum. The above spore-pollen spectrum is typical for the Lower Oligocene of the Czempin Formation.

The next distinguished spore-pollen assemblage was selected from a clayey-silts at a depth of 144.10–144.15 m. This assemblage was separated from the previous one by a sixteen-meter thick layer of sands. The frequency and a preservation state of the sporomorphs were generally satisfactory. Spores were represented by a few species among which abundantly occurred: *Laevigatosporites haardti* — up to 15.0%, as well as separately were found: *Neogenisporis neogenicus*, *Verrucatosporites balticus balticus*, *Baculatisporites primarius*, *B. nanus*, *Triplanosporites microsinuosus*, and *Camarozonosporites heskemensis*. The most important element in the spectra were formed by gymnospermes such as: *Pinuspollenites* — up to 20.5%, *Inaperturopollenites dubius* — up to 10.8%, *I. hiatus* — up to 9.1%, *Sciadopityspollenites* — up to 4.5%, *Sequoiapollenites* — up to 3.7%, *Cupressacites bockwitzensis* — up to 2.4%, and other taxa which occurred separately. Pollen of angiosperms were less numerous but the warmth-loving species such as *Castaneoideaepollis pusillus* — up to 5.9%, and *Tricolporopollenites pseudocingulum* — 4.0%, occurred in the highest proportions. Other such as: *Fususpollenites fusus*, *Platanipollis ipelensis*, *Quercoidites microhenrici*, *Q. henrici*, *Engelhardtioipollenites quietus*, *E. punctatus*, *Tricolporopollenites megaexactus*, *Platycaryapollis levis*, *Symplocoipollenites vestibulum* and *S. rotundus* did not amount 2.0%. Separately, there occurred taxa of lower thermal requirements.

On the basis of the studied spectrum an age of the discussed assemblage is not quite univocal. However, approximately it may be speculated that the studied assemblage came from the upper part of the Upper Oligocene (Chattian).

The next studied assemblage was recognized in a lignite seam at a depth of 134.20–137.55 m. The frequency of spomorphs and their preservation state were very good. In the spectra an occurrence of marine phytoplankton has not been noted. The spores were taxonomically differentiated but quan-

titatively they were not abundant. The following taxa have been recognized: *Neogenisporis neogenicus*, *Leiotriletes wolffii*, *L. maxoides*, *L. neddenioides*, *Triplanosporites microsinuosus*, *Radialisporis radiatus*, *Baculatisporites primarius*, *Retitriletes*, *Hamulatisporites rarus*, *Reticulosporis polonicus* and *Monoleiotriletes gracilis* as well as the different species from the *Stereisporites* (*sensu lato*) genus. The gymnosperms were dominant and represented by: *Pinuspollenites* — up to 19.0% and *Sequoiapollenites* — up to 13.0%, but less frequently occurred: *Inaperturopollenites dubius* — up to 6.3%, *I. hiatus* — up to 3.7%, *Cupressacites bockwitzensis* — up to 3.5%, *Sciadopityspollenites* as well as others. Pollen of the angiosperms were more numerous than the pollen of gymnosperms. The great significance was performed by the Palaeotropical geoflora taxa, mainly of the subtropical element — P2, such as *Tricolporopollenites pseudocingulum* — up to 17.0%, *T. megaexactus* — up to 14.4%, *T. bruehlensis* — up to 13.0%, *Myricipites bituitus* — up to 8.0%, *Quercoidites henrici* — up to 7.4%, *Myricipites coryphaeus* — up to 6.9%, *Platycaryapollenites* — up to 5.3%, *Tricolporopollenites exactus* — up to 5.0%, *Myricipites rurensis* — up to 3.8%, *M. microcoryphaeus* — up to 3.1%, *Tricolporopollenites dolium* — up to 2.8%, *Quercoidites microhenrici* — up to 2.8% and *Engelhardtioipollenites punctatus*. Taxa represented by the tropical element — P1 such as: *Symplocoipollenites latiporis* — up to 5.2%, *S. vestibulum* — up to 3.3%, *S. rotundus*, *Platycaryapollenites*, *P. miocaenicus*, *Platanipollis ipelensis*, *Arecipites pseudoconvexus*, *A. wiesaensis*, *A. lusaticus*, *Castaneoideaepollis pusillus*, *C. oviformis*, *Magnolipollis*, *Milfordia incerta*, *Triplopollenites robusuts* and *Verrutricolporites theacoides* occurred in a smaller quantities and they showed a higher thermal requirements. The pollen of Arctotertiary geoflora such as: *Alnipollenites verus*, *Betulaepollenites betuloides*, *Ericipites ericius*, *Faguspollenites*, *Ilexpollenites*, *Liquidambarpollenites stigmosus*, different species of *Nyssapollenites* and *Quercoidites* was not numerous. The above-discussed part of the profile is bipartite. In its lower part the domination pollen of the plants which showed a high thermal requirements (subtropical) as well as the spores of *Laevigatosporites haardti* were observed. In the upper part of the profile a share of the pollen, which came from the subtropical trees, has diminished and was replaced by more significant pollen of the warmth-loving shrubs.

The above mentioned spore-pollen assemblage with domination of the subtropical elements, of the Palaeotropical geoflora, may be correlated in a wide sense with the palynological spectra of the V spore-pollen *Quercoidites henrici* Zone, which characterized the II Łużyce Lignite Seam of the Middle Miocene Ścinawa/Krajenka Formation.

In the overlying lignite seam, sands and coaly silt deposits at a depth of 123.20–131.75 m have been distinguished a spore-pollen assemblage, very similar to the previous one. The spores did not form an important element. Among the gymnosperms, the bigger differences have not been noted and the following taxa were dominant: *Pinuspollenites* — up to 19.0%, *Abiespollenites* — up to 6.6%, *Inaperturopollenites dubius* — up to 5.8% and *Sequoiapollenites* — up to 5.7%. The differ-

ences in the spectrum in comparison with the underlying assemblage were mainly concerned the composition of the angiosperm pollen. Still the most important element in the spectra were two species such as: *Tricolporopollenites pseudocingulum* 11.2% and *Quercoidites henrici* 5.9%, but less numerous were warmth loving taxa. The significance of pollen of mixed forest trees of the Arctotertiary geoflora has increased and the following taxa have been recognized: *Quercoidites* — up to 8.7%, *Faguspollenites* — up to 5.7%, *Liquidambarpollenites* — up to 5.5%. Moreover, a share of the plants which preferred wet substratum has also increased and the following taxa have been identified: *Nyssapollenites* — up to 15.0%, *Inaperturopollenites dubius* — up to 5.8% and *Alnipollenites verus* — up to 5.7%. This assemblage as well as the previous one may define the **V** *Quercoidites henrici* Zone of the II Łużyce Lignite Seam within the Middle Miocene Ścinawa/Krajenka Formation. The differences reflect rather habitat changes than stratigraphical ones.

Above, in lignite and in the underlying silty-sand sediments at a depth of 112.00–121.90 m, the next spore-pollen assemblage has been distinguished. It was characterized by the same composition of sporomorphs. It showed a low frequency and poor preservation state of the sporomorphs. They were not abundant and significant. The gymnosperm pollen were slightly prevalent over the angiosperm one. The taxonomical differentiation was not significant. The following species and genera have been distinguished: *Pinuspollenites* — up to 27.0%, *Sequoiapollenites* — up to 13.0%, *Inaperturopollenites dubius* — up to 5.4% as well as separately occurred: *I. hiatus* and *Sciadopityspollenites*. From the angiosperms the following taxa such as: *Ericipites ericius* — up to 7.0–18.0%, *Engelhardtioipollenites punctatus* — up to 10.0%, *Myricipites* sp.sp. — up to 7.9% *Betulaepollenites betuloides* — up to 7.4%, *Myricipites rurensis* — up to 5%, *Alnipollenites verus* — up to 3.5%, *Nyssapollenites* — up to 2.7% occurred: as well as separately *Quercoidites* and *Faguspollenites* have been distinguished. In a coaly samples, pollen of the warmth-loving plants particularly *Tricolporopollenites exactus* 6.5–10.0%, *T. megaexactus* 5.9–8.5% and *T. bruehlensis* — 3.6–4.3% has been noted. The higher share of these taxa, have been particularly found in the sample at a depth of 112.90–112.95 m. Pollen of herbaceous plants such as: *Artemisiaepollenites*, *Graminidites* and *Sparganiaceapollenites* were not significant. Sporadically, in samples occurred the fragments of worn marine phytoplankton, as well as the separate pollen grains of the Normapolles group. Their occurrence suggested an erosion of the older sediments and redeposition among the Neogene sediments.

The above-discussed spectrum corresponds with the IIA Lubin Lignite Seam and is related to the **VI** spore-pollen *Tricolporopollenites megaexactus* Zone, which occurs in the Middle Miocene Pawłowice/Adamów Formation.

The successive studied spectrum has been distinguished in silty-sands and contains a coaly silt at a depth of 82.05–110.75 m. Sporomorphs in this spectrum showed a high frequency in the occurrence as well as a good preservation state. They manifested a high taxonomical differentiation among which the fol-

lowing taxa have been found: *Leiotriletes*, *L. wolffii*, *Hamulatisporis rarus*, *Neogenisporis neogenicus*, *Radialisporis radiatus*, *Baculatisporites primarius*, *Echinatisporis* and *Reticulosporis gracilis*, as well as a few species from the *Ste-reisporites* (*sensu lato*) genus also occurred. The gymnosperms were dominated and represented by *Pinuspollenites* — up to 42.0%, *Inaperturopollenites dubius* — up to 5.1%, and *Sequoiapollenites* — up to 4.5%, as well as a few other species from the *Zonalapollenites* genus — up to 2.6%, *Inaperturopollenites hiatus* — up to 2.3%, and *Abiespollenites* — up to 2.3% occurred. The pollen of angiosperms were abundantly represented and taxonomically differentiated, among which the following taxa dominated: *Alnipollenites verus* from 2.0 up to 29.0%, *Betulaepollenites betuloides* — up to 12.0%, *Ericipites ericius* — up to 9.5%, *Faguspollenites* — up to 8.8%, *Quercoidites* — up to 5.0%, different species of *Nyssapollenites* — up to 3.8%, *Tricolporopollenites megaexactus* — up to 3.3%, *T. pseudocingulum* — up to 2.3% and *Ulmipollenites undulosus* — up to 1.8%. Less abundant were Palaeotropical geoflora taxa such as: *Araliaceoipollenites euphori*, *A. edmundi*, *Arecipites psedoconvexus*, *Castaneoideaepollis oviformis*, *Tricolporopollenites bruehlensis*, *T. exactus*, *Myricipites*, *Platanipollis ipelensis* and *Verrutricolporites theacoides*.

Composition of this part of the spectrum, in spite of the lack of the index taxa should be compared with the **VII** spore-pollen assemblage of the *Iteapollis angustiporatus* Zone of the Middle Miocene Pawłowice/Adamów Formation.

In the uppermost part of lignite sediments at a depth of 90.60–91.65 m the last spore-pollen assemblages has been distinguished in this sequence. The frequency of the sporomorphs was high and their preservation state was satisfactory. Spores, which occurred regularly, did not form an important element. The gymnosperm plants were richly represented and the most numerous were the following taxa: *Pinuspollenites* — up to 26.0%, *Sequoiapollenites* — up to 8.5%, *Inaperturopollenites dubius* — up to 5.7%, *I. hiatus* — up to 3.2%, *Abiespollenites* — up to 5.2%, *Cupressacites bockwitzensis* — up to 3.2% and *Sciadopityspollenites* — up to 1.7%. However, in the whole assemblage the most dominant was the angiosperm pollen, represented abundantly by the following taxa: *Betulaepollenites betuloides* — up to 13.8%, different species from the *Nyssapollenites* genus — up to 11.0%, *Quercoidites* — up to 9.0%, *Alnipollenites verus* — up to 8.3%, *Faguspollenites* — up to 6.6%, *Ericipites ericius* — up to 6.3%, *Tricolporopollenites sinuosimuratus* — up to 3.3%, *Ulmipollenites undulosus* — up to 3.1% and *Vitispollenites* — up to 2.1%. Moreover, the pollen of herbaceous plants have been distinguished such as: *Sparganiaceapollenites sparganioides*, *S. magnoides*, *Graminidites*, *Cichoraecidites gracilis* and *Corsinipollenites*. The taxa belonging to Palaeotropical geoflora occurred regularly, however, they formed only a few percent of the whole assemblage and were represented by: *Tricolporopollenites megaexactus*, *T. exactus*, *T. pseudocingulum*, *T. dolium*, *Platanipollis ipelensis*, *Castaneoideaepollis oviformis*, *C. pusillus* and *Quercoidites henrici*. In the spectra at a depth of 90.90–91.10 and 91.10–91.15 m occurred a high amount of tricorporate pollen grains belonging to the *Carpinipites* genus which amounted from 6.9

to 29.7%. It was related to the Recent species of *Carpinus orientalis*. In sediments at a depth of 91.40–91.45 m the most numerous was *Tricolporopollenites exactus* which reached up to 32.0%. An increased share of the above-specified taxa has rather local character, connected with a type of habitat.

The above presented pollen spectrum is similar to the I Middle Polish Lignite Seam which was defined as the **VIII Celtipollenites verus** Zone, occurring in the the upper part of the Middle Miocene of the Poznań Formation. The index taxon occurred here rarely. The above-discussed assemblage occurred among the deposits, which terminated the Neogene sedimentation in the Łosiny 2/KB profile.

RACIAŻ II

In the Raciaż profile two assemblages have been distinguished (Table 10). In the lowermost part of the profile at a depth of 193.00–210.00 m among fern and moss have been found the Paleogene spores such as *Camarozonosporites heskemensis*. The gymnosperm pollen such as: *Inaperturopollenites dubius* — 7.0–22.0%, *Pinuspollenites* — 14.0–17.5% and *Sequoiapollenites* — 4.0–5.5% were dominant. Among the angiosperms characteristic taxa such as *Fususpollenites fusus*, *Platanipollis ipelensis*, *Tricolporopollenites staresedloensis* and *Tripoporopollenites megagranifer* have been recognized. Moreover, the occurrence of marine phytoplankton has been noted. Also, a presence of brackish and freshwater phytoplankton has been recognized in the small quantities.

The sporomorph assemblage with a high content of the *Fususpollenites fusus* as well as characteristic taxa of phytoplankton may suggest the Lower Oligocene age of the spectrum from the Czempin Formation sediments. In coaly silts at a depth of 153.20–155.30 m, the frequency of the sporomorphs was low; therefore the qualitative analysis has only been done. The distinguished taxa were the following: *Inaperturopollenites dubius*, *Pinuspollenites*, *Sequoiapollenites*, *Alnipollenites verus*, *Tricolporopollenites pseudocingulum*, *T. megaexactus*, *Ericipites callidus* and *Quercoidites* which formed an analogous spectrum to the pollen spectrum which derived from lignite of a depth of 148.20–148.60 m. In the above mentioned deposits the gymnosperm pollen are mainly represented by *Pinuspollenites* — 19.5%, *Inaperturopollenites dubius* — 15.0% and *Sequoiapollenites* — 10.0%. The most abundant was the angiosperm pollen among which the following taxa have been distinguished: *Tricolporopollenites megaexactus* — 12.0%, *Ericipites ericius* — 7.0%, *Tricolporopollenites pseudocingulum* — 5.0%, *Cornaceaepollis satzveyensis* — 5.0%, and *Tricolporopollenites exactus* — 3.0%. Phytoplankton has not been noted. This pollen spectrum is closely related to the composition of the Middle Miocene assemblages. Due to abundant occurrence of the *Tricolporopollenites megaexactus* and *T. exactus*, this assemblage may be compared with the **VI spore-pollen Tricolporopollenites megaexactus** Zone within the IIA Lubin Lignite Seam of the Pawłowie/Adamów Formation.

TUCHOLA-BIAŁOWIEŻA VI

Two spore-pollen assemblages, distinctively different to each other have been distinguished in the Tuchola-Białowieża VI profile (Fig. 13; Table 10).

The lower complex occurred among the silty sediments, which are separated from lignite series at a depth of 114.00–172.00 m. This complex contained characteristic Paleogene spores of the *Cicatricosisporites dorogensis* and *Camarozonosporites heskemensis* species. Gymnosperm pollen were represented by: *Pinuspollenites* — 3.5–20.0%, *Piceapollenites alatus* — 2.5–7.5% and *Inaperturopollenites dubius* which occurred in a smaller quantity. Within the angiosperms the following taxa have been distinguished: *Fususpollenites fusus* — 2.5–27.5%, *Castaneoideaepollis pusillus* — 5.0–10.5%, *Quercoidites henrici* — 2.0–5.5%, and also separately occurred: *Tricolporopollenites quisqualis*, *T. staresedloensis*, *Platanipollis ipelensis* and *Tripoporopollenites robustus* as well as index such as: *Cupanieidites eucalyptoides* and *Boehlenipollis hohli* species which did not occur above the Oligocene/Miocene boundary. Marine phytoplankton was rather rich. The results of the palynological analysis from this complex of the sediments point to the Lower Oligocene age of this spectrum. The V Lignite Seam of the Czempin Formation intercalates the described here silty sediments.

The upper complex was found in a silty clay sediments at a depth of 47.00–56.50 m. The gymnosperm pollen occurred in the increased amount and were represented by: *Pinuspollenites* — 12.0–22.5%, *Inaperturopollenites dubius* — 7.0–31.0% and *Sequoiapollenites* — 8.0–13.0%. Among the angiosperms a share of *Tricolporopollenites pseudocingulum* has increased up to 20.0% as well as very often-occurred *Myricipites* from 3.0 up to 10.0%. An abrupt increase in amount of the *Nyssapollenites* — up to 36.0%, at a depth of 54.00–54.50 m has been undoubtedly caused by the augmented humidity of substratum. A great significance was acquired by the Arctotertiary geoflora of a cool-temperate element represented by *Betulaepollenites betuloides*, *Carpinipites* and mosses of the Sphagnaceae family. Freshwater phytoplankton has been sporadically met and represented by: *Tetrapidites* and *Ovoidites ligneolus* together with other indeterminate taxa.

Composition of the above-mentioned assemblage, but particularly a high share of the *Tricolporopollenites pseudocingulum*, as well as the lack of marine phytoplankton, suggests that an age of the studied spectrum could be defined on the Middle Miocene of the Pawłowie/Adamów Formation. It is related to the **V spore-pollen Quercoidites henrici** Zone.

WYMYSŁOWO XI

Two spore-pollen assemblages have been distinguished in the Wymysłowo XI profile (Table 10). The lower assemblage has been recognized in a silty sediments at a depth of 84.50–89.10 m. Among the abundantly occurring spores,

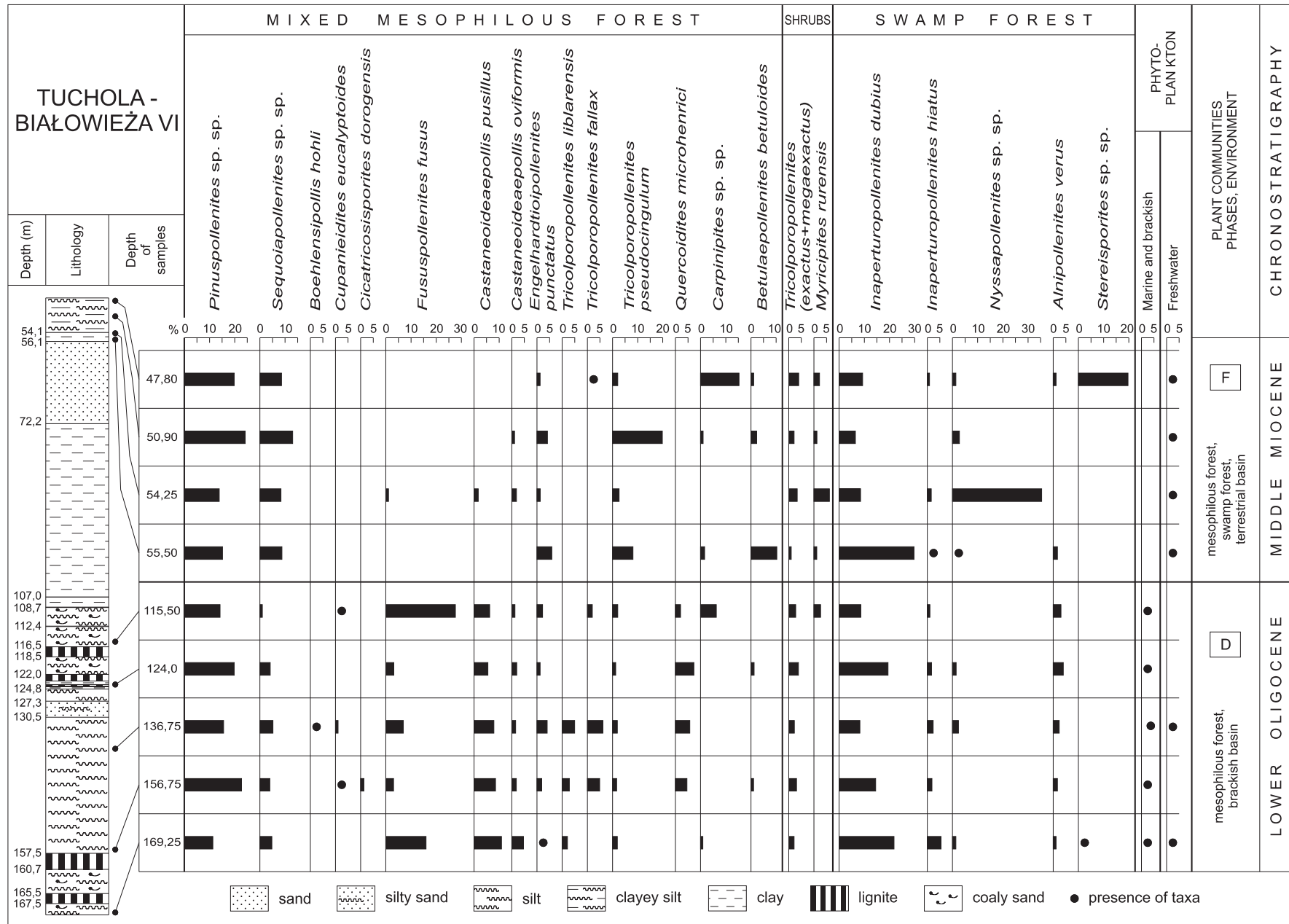


Fig. 13. Pollen diagram of Tuchola-Białowieża VI borehole

characteristic taxa such as *Camarozonosporites heskemensis* and *Cicatricosisporites dorogensis* have been found. The gymnosperm pollen were not so abundant, and represented by: *Inaperturopollenites dubius* — 12.5%, *I. hiatus* — 7.0% (altogether 19.5%) and *Pinuspollenites* — 6.5%. Among the angiosperms occurred the index *Cupanieidites eucalyptoides*, as well as the other dominant taxa such as: *Fususpollenites fusus* — up to 6.0%, *Castaneoideaepollis pusillus* — up to 12.5%, and in the smaller proportions occurred: *Tricolporopollenites quisqualis*, *Quercoidites microhenrici*, *Q. henrici*, *Platanipollis ipelensis*, *Milfordia incerta* and *Engelhardtioipollenites*. Marine phytoplankton occurred abundantly. The above-mentioned spectrum is most similar to the Lower Oligocene assemblages of the Czempin Formation.

The upper part of this profile occurred in lignite series at a depth of 43.00–46.50 m. A very low amount of the gymnosperm pollen grains which ranged from 7.5% to 11.5% has been noted. Although, the angiosperm pollen were rather abundant and represented by: *Engelhardtioipollenites punctatus* from 11.5 to 13.0%, *Myricipites rurensis* from 9.0 to 14.5%, *Betulaepollenites betuloides* — up to 10.0%, *Carpinipites* — up to 6.0% as well in a smaller quantities occurred: *Tricolporopollenites exactus*, *T. megaexactus* as well as others.

A major part of the studied pollen assemblage is represented by a shrub community and may be compared with the VI *Tricolporopollenites megaexactus* Zone. It was a warm period during the Middle Miocene, related to the IIA Lubin Lignite seam of the Pałowice/Adamów Formation.

OBROWO III

Two different palynomorph assemblages have been distinguished in the Obrowo III borehole (Table 10). The Paleogene spores of *Camarozonosporites heskemensis* and *Cicatricosisporites dorogensis* have been found in silt deposits at a depth of 159.00–168.60 m. The gymnosperms have been represented by the following taxa: *Pinuspollenites* — up to 14.5%, *P. alatus* — up to 8.5%, *Inaperturopollenites dubius* — 10.0–17.0%, *Sequoiapollenites* — 7.0–8.0%, *Sciadopityspollenites* — up to 4.5%. The above studied assemblage may be dated as Paleogene, based on the occurrence of the *Trudopollis* pollen from the Normapolles group, as well as also the other species which frequently occur in Paleogene such as: *Fususpollenites fusus* — up to 7.0%, *Castaneoideaepollis pusillus* — 7.0–9.0%, *Platanipollis ipelensis*, *Tricolporopollenites staresedloensis*, *Quercoidites microhenrici*, *Engelhardtioipollenites quietus* and *Tripoporopollenites robustus*. The most important was the occurrence of the index species of *Cupanieidites eucalyptoides*. The taxa, which occur either in Paleogene and Neogene have been also found such as: *Tricolporopollenites megaexactus* — up to 4.5% and *Milfordia incerta*. Marine phytoplankton has also been noted. The studied palynological spectrum pointed to a Paleogene age of this assemblage, however, it can not be univocally defined. Occurrence of abundant pollen from the Normapolles group most likely suggests the Upper Eocene age of the assemblage of the Pomorze Formation.

Silty deposits at a depth of 64.00–65.00 m have shown Paleogene spectra. Among the spores occurred: *Camarozonosporites heskemensis*, but from the gymnosperms: *Pinuspollenites* — up to 12.5%, *Piceapollenites alatus* — up to 4.0% *Inaperturopollenites dubius* — up to 9.5%, *Sequoiapollenites* and *Sciadopityspollenites*. The angiosperm plants were represented by: *Fususpollenites fusus* — up to 12.0%, *Castaneoideaepollis pusillus* — up to 18.0% as well as: *Quercoidites henrici*, *Q. microhenrici*, *Platanipollis ipelensis*, *Tricolporopollenites staresedloensis* and *Juglandipollis maculosus*. Moreover, the occurrence of marine phytoplankton has also been noted.

The above-mentioned spectrum is most closely related to the Lower Oligocene assemblages recognized in the Czempin Formation.

MĘDROMIERZ V

Three assemblages have been distinguished at a depth of 87.00–175.60 m in the Mędromierz V borehole (Table 10). Pollen of the gymnosperms occurred not abundantly at a depth of 173.20–175.60 m, with dominate species such as: *Inaperturopollenites dubius* — up to 20.0%, *Pinuspollenites* — up to 9.5% and *Piceapollenites alatus* — up to 7.0%. A higher share of the angiosperms, was particularly marked by: *Castaneoideaepollis pusillus* — up to 7.0%, *Quercoidites henrici* — up to 4.5%, *Tricolporopollenites megaexactus* — up to 5.0%, *Ericipites ericius* — up to 4.5%, *Quercoidites microhenrici* — up to 3.0%, *Castaneoideaepollis oviformis* — up to 3.0%, *Tricolporopollenites pseudocingulum* — up to 3.0% as well as by less numerous species such as: *T. liblarensis*, *T. fallax*, *Fususpollenites fusus*, *Platanipollis ipelensis* and *Engelhardtioipollenites quietus*. Marine phytoplankton occurred sporadically.

The analysed palynomorph assemblage did not contain the index taxa, however, occurring here spores and pollen are the most similar to the Upper Oligocene assemblage of the Upper Mosina Formation.

In clayey silt sediments at a depth of 101.80–109.50 m was noted the increase of the gymnosperm pollen mainly of *Pinuspollenites* — 33.5–40.0% and *Sequoiapollenites* — 4.0–15.0%, but the others occurred in maximum number up to 8.0%. Among the angiosperms the dominant taxa were: *Nyssapollenites* — up to 13.0%, *Betulaepollenites betuloides* — up to 4.0%, *Quercoidites* — up to 6.0%, *Faguspollenites* — up to 4.0% and *Ericipites ericius* — up to 5.0%. Moreover, the pollen of herbaceous plants such as: *Sparganiaceapollenites* and *Graminidites* have also been found. Scarce freshwater phytoplankton occurred, as well. The presented above assemblage is similar to the IX spore-pollen *Tricolporopollenites pseudocingulum* Zone, in which sporadically occurred the index taxon. This assemblage is correlated with the upper part of the Middle Miocene of the Poznań Formation.

Different composition of spectrum has been isolated from the grey-greenish clays at a depth of 87.00–100.60 m. The relatively rich spore assemblage has been recognized and it comprised characteristic taxa such as: *Gleicheniidites*, *Toroisporis*, and *Cicatricosisporites chattensis*. Besides, the dominant gymnosperm pollen occurred also: *Pinuspollenites* — 20.0–

28.0%, *Piceapollenites alatus* — 11.0–22.0%, *Inaperturopollenites dubius* — up to 9.5%, *Inaperturopollenites hiatus* — 3.5–8.0%, *Sciadopityspollenites* — 4.5–5.5%, and *Sequoiapollenites* — 4.5–5.5%. Contrary, to the rich occurrence of gymnosperms, the angiosperms were poorly represented both in number of taxa and the percentage frequency. The following taxa have been recognized: *Castaneoideaepollis pusillus* — up to 6.5%, *Engelhardtioipollenites punctatus* — up to 4.5%, *Platanipollis ipelensis*, *Tricolporopollenites staresedloensis*, *Castaneoideaepollis oviformis*, *Quercoidites henrici*, and *Engelhardtioipollenites quietus* as well as others. Marine phytoplankton occurred abundantly.

The studied spectrum may be dated on the Upper Eocene/Lower Oligocene age, which is also recognized from the Lower Mosina Formation.

Taking into consideration the succession of palynological dated assemblages, which occurred in the Mędromierz V borehole, the reversed stratigraphical sequence of the strata has been registered.

JELEŃCZ IV

In the Jeleńcz IV profile at a depth of 91.00–160.00 m three different spore-pollen assemblages have been distinguished (Table 10). The lowermost assemblage was recognized in coaly silts at a depth of 157.10–160.00 m. The spores occurring in this part of profile are the following: *Camarozonosporites heskemensis* and *Gleicheniidites* as well as others. The gymnosperm pollen were not abundant and weakly differentiated. Index taxa among the angiosperm have also been noted such as: *Fususpollenites fusus* — up to 7.0%, *Castaneoideaepollis pusillus* — up to 12.5% and *C. oviformis*, *Triporopollenites robustus*, *Engelhardtioipollenites* and *Platanipollis ipelensis* as well as *Intratiporopollenites instructus*. A few genera of marine, brackish and freshwater phytoplankton have also been recognized. On the basis of the above-mentioned data, it should be concluded the Paleogene age of the spectrum, which is characteristic for the Lower Oligocene developed in the Czempin Formation.

Sporomorph assemblages have been found in silty intercalations among sands at a depth of 137.00–138.00 m as well as lignite sediments from a depth of 121.10–125.60 m, and they both showed a similar composition. A small amount of gymnosperm pollen was indicated in coaly deposits, however, in silty sediments the *Sequoiapollenites* reached up to 29.0%. Lower part of this profile was dominated by: *Pinuspollenites* — up to 10.0%, *Piceapollenites alatus* — up to 5.5% and *Inaperturopollenites dubius* — up to 8.0%. Among the angiosperm pollen a high amount was showed by *Tricolporopollenites exactus* — up to 18.0%, *T. megaexactus* — up to 10.5%, different species of *Ilexpollenites* genus — altogether up to 13.0%, *Ericipites ericius* — 7.5%, *Carpinipites* — 6.0%, as well less numerous: *Quercoidites henrici*, *Engelhardtioipollenites punctatus*, *Myricipites rurensis*, *Tricolporopollenites pseudocingulum*, *Quercoidites*, *Nyssapollenites* and others have been found. Marine and freshwater phytoplankton has not been noted.

The above-mentioned data suggest the Neogene age of this assemblage. A high amount of the *Tricolporopollenites megaexactus*, and *T. exactus* as well as other taxa represented by shrub communities suggest the comparison of these spectra with the VI spore-pollen *Tricolporopollenites megaexactus* Zone, connected with the IIA Lubin Lignite Seam of the Middle Miocene Pawłowice/Adamów Formation.

The studied palynological assemblage of lignite at a depth of 91.00–91.50 m, was different from the previously studied assemblages. More often occurred a temperate pollen taxa such as: *Betulaepollenites betuloides* — up to 22.5%, *Faguspollenites* — up to 7.0% as well as *Alnipollenites verus*, *Celtipollenites*, *Carpinipites*, *Ulmipollenites undulosus*, *Aceripollenites*, *Liquidambarpollenites* and *Quercoidites*. A share of herbaceous pollen and aquatic plants has been clearly marked and represented by such taxa as: *Sparganiaceae-pollenites*, and *Umbelliferoipollenites*. The warmth-loving taxa occurred, scarcely.

The above-mentioned spectrum is similar to the VIII spore-pollen *Celtipollenites verus* Zone, which characterizes the I Middle Polish Lignite Seam of the Middle Miocene Poznań Formation.

KAMIEŃ 2/KA

Three palynomorph assemblages have been distinguished in the Kamień 2/Ka profile (Table 10). In the lowermost, underlying silt deposits at a depth of 207.50–207.60 m, occurred the index spores such as: *Cicatricosisporites paradorogensis* and the gymnosperm pollen which amounted up to 50.0%, where the following taxa have been recognized: *Inaperturopollenites dubius* — up to 25.0%, *I. hiatus* — up to 11.0%, *Pinuspollenites* — up to 2.5% and *Sequoiapollenites* — up to 5.0%. The most important feature of this assemblage was the occurrence of the stratigraphically important species belonging to angiosperm pollen such as: *Cupanieidites eucalyptoides*, *Medicopolpollis compactus*, *Reductipollis* and *Fususpollenites fusus* — up to 12.0%. Marine phytoplankton has also been noted. The studied here assemblage suggests the Upper Eocene/Lower Oligocene age occurring in the Lower Mosina Formation.

In sediments overlying brown silt deposits at a depth of 161.70–167.80 m has been isolated an assemblage in which a share of the gymnosperm pollen reached up to 55.0%. The recognized here taxa are as follows: *Inaperturopollenites dubius* — up to 21.5%, *I. hiatus* — up to 7.0%, and *Pinuspollenites* — up to 13.0%. Among the angiosperms occurred the index taxa such as: *Dicolpopollis kockelii*, *Dicolporopollis middendorfi*, *Sapotaceoideaepollenites* and *Triporopollenites megagranifer*. Occurrence of the marine phytoplankton was also important. The specified above spectrum may suggest the Oligocene age, which is characteristic for the Czempin Formation.

Silty sediments together with lignite at a depth of 73.70–73.80 m comprised a pollen spectrum which was composed of 65.0% of gymnosperm pollen, with the dominant share of *Pinuspollenites* — up to 19.5% and *Sequoiapollenites* — up to 28.0%. Among the angiosperms the most numerous

was *Tricolporopollenites pseudocingulum* — up to 10.0%, less frequently occurred: *Engelhardtioipollenites punctatus*, *Myricipites rurensis*, *Tricolporopollenites megaexactus*, *Quercoidites henrici* and others.

The studied spectrum is not typical but similar to the assemblage, which occurred in the **V** *Quercoidites henrici* Zone of the II Łużyce Lignite Seam of the Middle Miocene Ścinawa/Krajenka Formation.

PIŁA-MŁYN V

In the Piła-Młyn V borehole at a depth of 19.20–174.20 m four assemblages which differ to each other have been distinguished (Table 10). In silty sediments at a depth of 173.70–174.70 m, among a small amount of spores occurred the index species such as: *Camarozonosporites heskemensis* and *Gleicheniidites*. The gymnosperm pollen have been mainly represented by: *Pinuspollenites* — up to 20.0%, *Piceapollenites alatus* — up to 7.5% and *Inaperturopollenites dubius*. The most numerous among the angiosperms were *Fususpollenites fusus* — up to 25.0%, the rest of the taxa did not amount to 3.5% such as: *Tricolporopollenites megaexactus*, *Castaneoideaepollis pusillus*, *Platanipollis ipelensis*, *Tricolporopollenites staresedloensis*, *Engelhardtioipollenites quietus*, and *Quercoidites henrici*. Rich marine phytoplankton assemblage has also been found.

The given data showed that it was the Lower Oligocene assemblage, which was also recognized in the Czempin Formation.

In silty sands and lignite sediments at a depth of 125.60–131.40 m have been found another assemblage which comprised numerous spores amounted from 26.0 up to 41.5%, mainly represented by *Stereisporites* (= *Sphagnum*), which formed a facial element. The gymnosperm pollen occurred in a small quantities and were represented by: *Pinuspollenites* — 8.5–14.0%, *Piceapollenites alatus* — up to 3.5% and *Inaperturopollenites dubius* — 4.5–5.0%. Among the angiosperms the most abundant were: *Engelhardtioipollenites punctatus* — 3.0–8.5%, *Tricolporopollenites exactus* — 3.0–8.0%, *Eriopites ericius* — 1.5–9.0%, *E. callidus* — up to 4.5% and *Quercoidites* — up to 4.0%. A slight share of herbaceous pollen has also been noted such as: *Graminidites*, *Persicarioipollis*, *Sparganiaceapollenites* as well as freshwater phytoplankton also occurred.

The above studied spectrum it slightly characteristic, however, is most closely similar to the **VI** *Tricolporopollenites megaexactus* zone, which characterized the IIA Lubin Lignite Seam of the Middle Miocene Pawłowice/Adamów Formation.

In sandy silts at a depth of 86.00–86.10 m, has been recognized a spectrum, which comprises up to 20.0% of spores without the stratigraphical significance. A share of the gymnosperm pollen in this spectrum reached up to 31.5%. The dominant were pollen represented by: *Pinuspollenites*, *Inaperturopollenites dubius*, and *Sequoiapollenites* — each element reached up to 8.5%. A share of the angiosperms reached up to 50.0%. The most numerous were the following species: *Betulaepollenites betuloides* — up to 15.0%, *Quercoidites* —

up to 10.0%, *Nyssapollenites* — up to 7.0%, *Alnipollenites verus* — up to 4.0% as well as in a small amount occurred other taxa. Phytoplankton was typical for a freshwater habitat.

The results of the palynological analysis of the studied sediments showed its great similarity with the **IX** *Tricolporopollenites pseudocingulum* Zone, which define the IA Oczkowie Lignite Seam of the Middle Miocene Poznań Formation.

The lowermost studied complex of sediments from the Piła-Młyn V profile comprised lignite and coaly-sandy-silt sediments at a depth of 19.20–34.20 m. Spectra from this part of the profile showed many common features. Spore occurred here sporadically. A share of gymnosperm pollen was abundant thanks to the occurrence of *Pinuspollenites* — 9.5–39.5% and *Sequoiapollenites* — up to 18.0%. The rest of the taxa did not amount 10.0%. The angiosperm plants were richly represented by typical Neogene taxa: *Tricolporopollenites pseudocingulum* — up to 20.5%, *Engelhardtioipollenites punctatus* — up to 10.0%, *Tricolporopollenites exactus* — up to 7.5%, *Eriopites ericius*, *Nyssapollenites*, *Myricipites rurensis* and *Myricipites bituitus*. Freshwater plankton has also been noted.

The above studied spectrum with a high amount of the *Tricolporopollenites pseudocingulum* is most closely similar to the **V** *Quercoidites henrici* Zone, which characterizes the II Łużyce Lignite Seam of the Middle Miocene Ścinawa/Krajenka Formation.

The Piła Młyn V similarly as the Mędromierz V profiles shows the reverse stratigraphical sequence of the strata.

GOSTYCYN IV

In sediments at a depth of 68.20–163.00 m five spore-pollen assemblages have been distinguished (Fig. 14; Table 10). The oldest studied assemblage in the Gostycyn IV profile came from silty sediments at depths of 162.40–163.00 and 155.00–156.00 m. Fern and moss spores were mostly represented by a few long-living species, however, only one *Camarozonosporites heskemensis* has stratigraphical significance. The dominant were gymnosperm pollen such as: *Inaperturopollenites dubius* — up to 22.5%, *Pinuspollenites* — up to 14.0%, *Piceapollenites alatus* — up to 5.0% and *Inaperturopollenites dubius* — up to 6.5%, as well as other taxa were less abundant. The following index species were recognized among the angiosperm such as: *Boehlenipollis hohli* and *Cupanieidites eucalyptoides*. Moreover, a great share of the *Fususpollenites fusus* — up to 28.0% and other warmth-loving elements have been noted such as: *Castaneoideaepollis pusillus*, *Milfordia incerta*, *Engelhardtioipollenites quietus*, *Tripoporopollenites megagranifer*, *Platanipollis ipelensis*, *Tricolporopollenites staresedloensis*, *Quercoidites henrici*, *Quercoidites microhenrici*, *Engelhardtioipollenites punctatus*, *Tricolporopollenites megaexactus*, *T. exactus* and *Eriopites ericius*. Occurrence of marine phytoplankton has also been noted.

The above studied spectrum is most closely related to the Lower Oligocene assemblages from the Czempin Formation.

The different spore-pollen assemblage has been found in lignite sediments out of a depth of 113.00–121.00 m. The gym-

nosperms have been represented by the following taxa: *Pinuspollenites* — up to 22.5%, *Inaperturopollenites dubius* — up to 12.0%, *Sequoiapollenites* — up to 8.0% and others. The angiosperms occurred quite abundantly with a surplus of: *Tricolporopollenites pseudocingulum* — up to 25.0%, *Nyssapollenites* — up to 20.0%, *Liquidambarpollenites* — up to 1.5%, *Alnipollenites verus* — 5.0%, and *Ericipites ericius* — up to 5.0%. Rarely occurred *Quercoidites henrici*, *Engelhardtioipollenites quietus*, *Castaneoideaepollis pusillus*, *Fususpollenites fusus*, *Platanipollis ipelensis*, *Tricolporopollenites fallax*, *Nyssapollenite* and *Ericipites ericius*. Also, occurrence of freshwater phytoplankton has been noted.

The above mentioned spectrum with a high number of the *Tricolporopollenites pseudocingulum* and the numerous share of the warmth-loving taxa is characteristic for the **V *Quercoidites henrici* Zone**, which was noted from the II Łużyce Lignite Seam of the Middle Miocene Ścinawa/Krajenka Formation.

Similar features have been recognized in the spectra found in three layers of lignite at a depth of 68.20–90.60 m. Among the most numerous spores occurred: *Laevigatosporites haardti* — up to 16.0%. The gymnosperm pollen have not been richly represented, apart from *Pinuspollenites* — up to 19.5% and *Inaperturopollenites dubius* — up to 29.5%. In the bigger amount occurred the angiosperms such as: *Nyssapollenites* — up to 29.5%, *Alnipollenites verus* — 7.0–38.0%, *Betulaepollenites betuloides* — 3.0–10.0%, *Quercoidites* — up to 10.0%,

Ulmipollenites undulosus — 4.0–11.0% and *Pterocarya-pollenites*. Frequently occurred also pollen of herbaceous plants such as: *Sparganiaceapollenites polygonalis*, *Graminidites*, *Persicarioipollis*, *Tubulifloridites*, *Umbelliferoipollenites* and *Artemisiaepollenites*. Freshwater phytoplankton has also been observed.

The studied pollen spectrum is most similar to the **IX *Tricolporopollenites pseudocingulum* Zone**, which characterized the IA Oczkowice Lignite Seam of the Middle Miocene Poznań Formation.

LISIE JAMY X

In this spectrum in a lignite sediments at a depth of 68.10–73.00 m, the most important were gymnosperm pollen represented by: *Pinuspollenites* — 25.0% and *Piceapollenites alatus* — 7.5%, but others occurred in a scarce quantities (Table 10). The angiosperm plants were mainly represented by: *Tricolporopollenites pseudocingulum* — up to 17.0%, *Nyssapollenites* — up to 12.5%, and *Tricolporopollenites exactus*, *Alnipollenites verus*, *Ericipites ericius* and *Quercoidites henrici*. Freshwater phytoplankton occurred sporadically.

The studied spectrum is similar to the **V *Quercoidites henrici* Zone**, which has been recognized in the II Łużyce Lignite Seam of the Middle Miocene Ścinawa/Krajenka Formation.

PLANT COMMUNITIES AND CLIMATIC CHANGES IN PALEOGENE AND NEOGENE

CHARACTERISTICS OF THE PLANT COMMUNITIES

One of the most important aims of the pollen analysis is to compare the external morphological features of fossil genera and species of the spores and pollen grains with the contemporary taxa. Recently, such efforts have been undertaken several times by Nagy, 1985, 1992; Planderová, 1990; Kohlman-Adam-ska, 1993; Planderová *et al.*, 1993; and Ziemińska-Tworzydło *et al.*, 1994a, b. In many cases it is possible to define the botanical affinity of the fossil sporomorphs on the family or genus level. Using this method it is possible to reconstruct the plant communities.

In the process of reconstructing the plant communities, the frequency of the specified taxa plays a very important role. This results from the preservation state of the pollen in the sediments but it also depends on other factors such as: — the primary production of the pollen by the individual plant species; — the way the pollen spreads — wind, water, insects etc, as well the distance from the deposition place. The pollen of anemophilous plants may be transported for considerable distances, while the pollen of entomophilous plants more often occur *in situ*. The secondary reasons for various amounts of the pollen are the condition existing during the accumulation of the deposits causing sometimes a selective distribution of pollen which depends on the different resistance of the cell membrane of the pollen grains to the process of sedimentation and

diagenesis. The degree of the destruction of the sporomorphs is affected by erosion and periods of aridity of the basin as well as by emergence of unconsolidated sediments. All the above-specified factors have a great influence on the picture of the pollen spectrum found in the studied sequences.

The identification of the botanical affiliation of fossil taxa, enable us to interpret the studied spore-pollen assemblages with regards to the dominant plant communities. In the reconstructed plant communities the morphological naming of sporomorphs has been replaced by a botanical terminology, which also gave the possibility to make conclusions about ecological and palaeogeographical conditions. Including the botanical taxa to specified plant communities; only one taxon on the family or genus rank has been related with most typical community, although some of them might have belonged to several communities. In the fossil material the taxonomical assignments of the lowest rank have been referred to the genus level, but within one genus a few species from different habitats may occur. Thus, it is not possible to decisively infer how many percentages of the specified taxon occur in one or the other community. For example *Alnus* may occur in a swamp forest on the low peat-fens; or in a riparian forest along the rivers on alluvial terraces. Another genus such as *Pinus* may grow either in a coniferous forest, a mixed forest as well as in a swamp forest. A certain indicator of the affiliation of the defined taxa to

a particular community may be the presence of other accompanying taxa.

Each specified taxon has been included into one from the two-geoflora assemblages such as Palaeotropical — P or Arctotertiary — A and within each geoflora to only one of the two palaeofloristic elements such as: P1 — tropical, P2 — subtropical, A1 — warm-temperate and A2 — cool-temperate (Appendix B). The definition of geoflora and the palaeofloristic elements has been used according to Planderová *et al.* (1993); Ziemińska-Tworzydło *et al.* (1994a).

Taking into account the above assumptions, the reconstruction of the plant communities and their succession during Paleogene and Neogene periods of the Pomeranian Lakeland has been performed for the first time.

While making the diagrams from four profiles (Figs. 11–14), the defined taxa have been grouped according to habitat types of the plant communities, ranging from the driest to the most humid one. Criteria of occurrence of the plant communities during Paleogene and Neogene proposed by Sadowska (1977) and Kohlman-Adamska (1993) were taken into consideration. On the left hand side on the diagrams was placed a mixed forest community, of a character of mesophilous forest in a wide sense, which usually is placed as far as possible from the aquatic basin. To the above-mentioned community have been included plants of dry-coniferous and moderately humid mesophilous forests (according to Kornaś, Medwecka-Kornaś, 1986; Mai, 1995) as well as the riparian forest. The studied communities have been placed on diagrams in the following succession: shrubs, swamp forest, herbaceous and aquatic plants.

After analysing the diagrams made according to the above-specified principles (Figs. 11–14) it was possible to examine the dominant geofloristic elements to reconstruct the plant communities. Spectra of similar taxonomical composition have been grouped into plant community phases. This division provides information connected with the succession of the plant communities and has a local palynostratigraphical character. All the defined taxa have been listed in Appendix B, where besides their taxonomical and botanical affiliation the type of the plant community in which the taxon occurs has been specified. It was also possible to distinguish in the studied material the plant communities of a local character which play an important role in the formation of lignites.

To illustrate changes of the Oligocene and Miocene plant communities, the cyclograms have been done for all the studied plant communities phases at that time in two main profiles (Fig. 15). The comparison of the cyclograms shows considerable similarities between the analogous phases in both profiles and, therefore, the cyclograms may be very helpful in palynostratigraphical correlation. Moreover, the changes in the percentage contribution of the specified plant communities seen in the cyclograms of the successive phases show the changes in the vegetation cover of the studied area.

The changes in the ratio between the particular geofloristic elements are shown in the charts which illustrate the share of Palaeotropical and Arctotertiary geoflora elements in the phases of the plant communities attributed to both model profiles in Oligocene and Miocene (Fig. 16).

PHASES OF THE DOMINANT PLANT COMMUNITIES

Reconstruction of the plant development in the studied area was based on the data from the following profiles: Komorza 1/KB, Łosiny 2/KB, Tuchola-Białowieża VI and Gostycyn IV (Fig. 11–14). The other profiles were correlated with the model profiles of Komorza 1/KB and Łosiny 2/KB. The successive phases of the plant communities have been marked letter symbols (A–K).

Phase A, the oldest phase established in the Paleogene sediments of the Middle Paleocene, contains the first recognized plant assemblage in the Komorza 1/KB and Łosiny 2/KB profiles (Figs. 11, 12). The core of this assemblage, was formed by rich marine phytoplankton, with the dominant share of Dinoflagellata cysts, characteristic of the marine basin. This relatively deep marine basin was reached by the rare spores which were transported from the land and represented by: Cyatheaceae, Gleicheniaceae, Lycopodiaceae, Lygodiaceae and Pteridaceae families as well as the sporadic pollen grains of coniferous trees represented by *Pinus*, *Cedrus* and *Sciadopitys*. Also, some pollen grains of thermophilous plants and elements of the mesophilous forest of *Castanea*, *Platanus* and *Engelhardtia* genera as well as the pollen of an unknown botanical affinity, mainly from the Normapolles group have been met. The long distance-journey of the pollen from the land to the place of accumulation in the marine basin was evidenced in the spectra by the sporadically occurring pollen of the angiosperms. Supposedly, the climate dominating at that time was subtropical.

Phase B has been established in the spectrum of the Upper Eocene sediments in the Obrowo III profile, dated on the basis of phytoplankton. In the studied assemblage the spores from the Lycopodiaceae and Lygodiaceae families have been recognized. Pollen of Palaeotropical element were dominant and represented by the *Castanea*, *Engelhardtia* and *Eucalyptus*, as well as the early Paleogene species from the subfamily Quercoideae and the family Hamamelidaceae occurred. Quite often the pollen of an unknown botanical affinity, also from the Normapolles group were found. Sporomorphs which were deposited in the marine sediments with abundant number of phytoplankton occurred more frequently in a deeper part of the shelf. On the seashores grew the mesophilous forest with a great share of thermophilous trees, as well as with clubmosses and ferns in the undergrowth. A character of the plant assemblages pointed to subtropical climate at that time.

Phase C has been established in the spectra of the sediments which were dated on the basis of phytoplankton on the Upper Eocene–Lower Oligocene age in the Kłodawa 4/Kł, Kłodawa 5/Kł, Mędromierz V and Kamień 2/Ka profiles. In the marine sediments with abundant number of phytoplankton, the pollen of anomophilous plants, which were better adapted to a long distance-journey were also preserved. On the basis of the pollen spectrum it may be concluded that shores of marine basin were vegetated by mixed mesophilous forest with a considerable share of the thermophilous plants represented by the Palaeotropical geoflora such as: *Castanea*, *Platanus* and

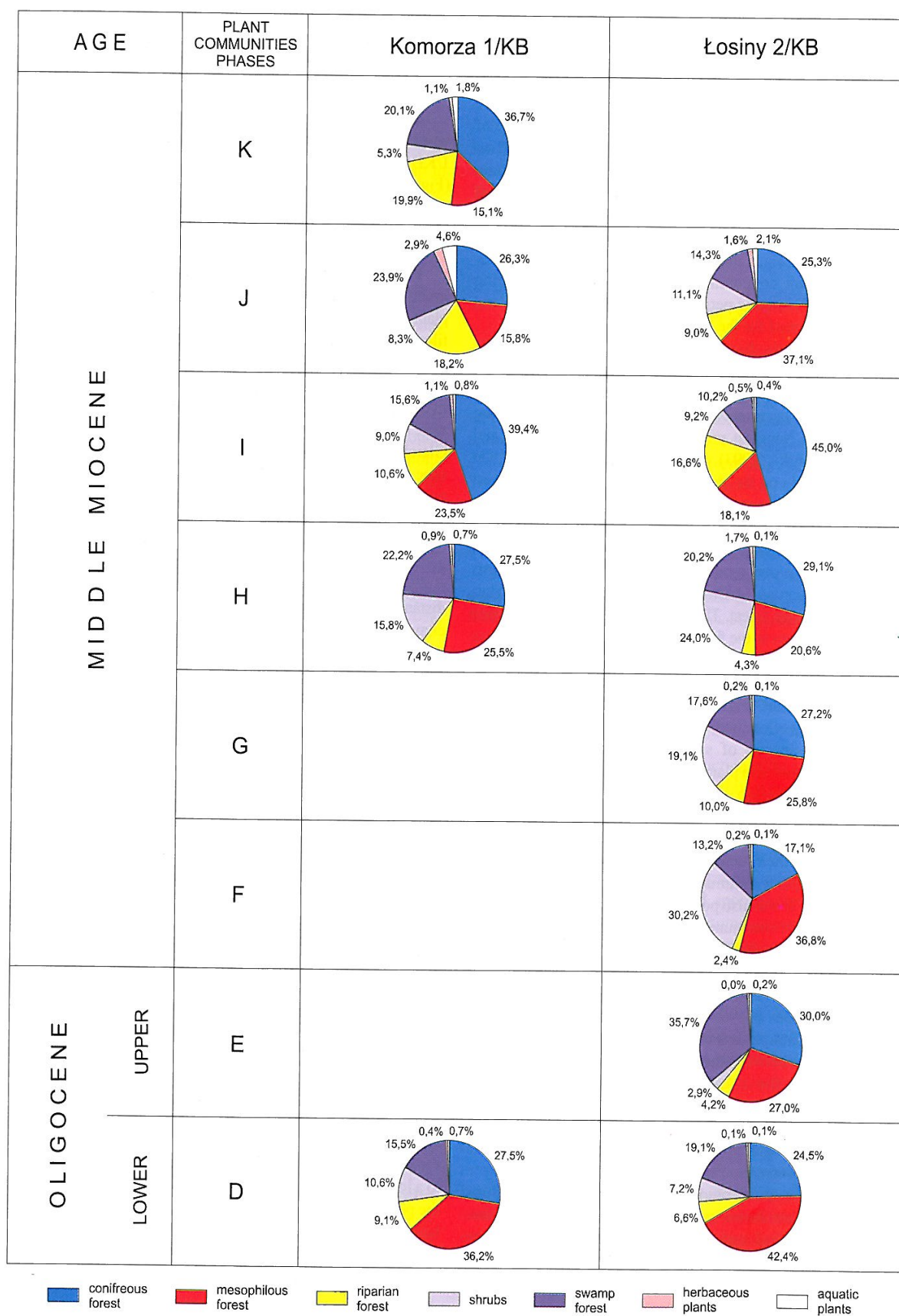


Fig. 15. Plant communities of D–K phases of Komorza 1/KB and Łosiny 2/KB boreholes

Engelhardtia as well as by Myrtaceae and Restionaceae, and the older genera of *Quercus* and Fagaceae represented by the *Fususpollenites fusus*. In the forest communities occurred also the plants of a pollen grain structure similar to Cyrillaceae-Clethraceae as well as other plants of an unknown botanical affinity, which produced pollen, which had not contemporary equivalents such as: *Mediocolpopollis compactus* and *Reductipollis*. Phytoplankton also occurred suggesting the deposition in the shallower, strongly hydrodynamic part of the shelf basin. The climate during this period was most likely subtropical.

Phase D defines the Paleogene pollen and phytoplankton assemblages of the Lower Oligocene deposited in the marine basin. It occurs in sediments of the majority of profiles in the Tuchola area such as: Komorza 1/KB (Fig. 11), Łosiny 2/KB (Fig. 12), Raciąż II, Tuchola-Białowieża VI (Fig. 13), Wymysłowo 11, Obrowo III, Jeleńcz IV, Kamień 2/KA, Piła-Młyn V, Gostycyn IV (Fig. 14), Kłodawa 4/K1, Kłodawa 5/K1, Myśligoszcz 1, Gronowo 2, Gronowo 3, Łyskowo PG 1 and Wilcze IG 1. At that time in the marine basin occurred the abundant and differentiated phytoplankton. In the lower part of this phase species predicting the beginning of marine transgression were dominant, later these species showed the outer shelf facies. In the higher part of this phase phytoplankton of shallow marine facies was more significant. On the land, plant communities of the mesophilous forest with numerous Palaeotropical elements were dominant such as: *Castanea* and *Engelhardtia* (represented by the two Paleogene species), *Trigonobalanus*, *Platanus* and *Parrotia*, *Eucalyptus* as well as *Quercus* (represented by Paleogene species) and the representatives of the families Cyrillaceae-Clethraceae, Restionaceae, Arecaceae and Sapotaceae. Moreover, the thermophilous elements of coniferous forest such as: Taxodiaceae-Cupressaceae, *Sciadopitys*, *Pinus* and *Podocarpus* also occurred. The dominant role has been played by a mixed, mesophilous forest community which reached up to 42.0%, with a considerable share of the evergreen trees of a higher thermal requirements, very often of an unknown botanical affinity, growing in a subtropical climate. Elements of swamp forest, which reached up to 19.0%, had a smaller significance. Ferns and clubmosses occurred in the undergrowth of this forest. The considerable share has been reached by the Palaeotropical geoflora taxa up to 42.0% (Figs. 15, 16).

Phase E occurred in the terminal part of Oligocene. It has been defined on the basis of the spectra from Łosiny 2/KB (Fig. 12) and Mędromierz V profiles, from clayey silt sediments of the regressive stage of the Oligocene sea. Marine basin shrank at that time and finally disappeared. The newly deposited sediments periodically immersed which is shown by the poorly preserved and scarce marine phytoplankton, as well as by worn sporomorphs with traces of corrosion on the grain surface. On the seashore grew mixed, mesophilous forests, which were poorer in species than during the Lower Oligocene and characterized by a considerable number of *Pinus*, *Sciadopitys* and *Sequoia*. Warmth-loving species of mesophilous forest such as *Castanea*, *Platanus*, *Platycarya* and *Symplocos*, older species of *Quercus*, representatives of the Myricaceae and Fagaceae families from the subfamilies Fagoideae and Quercoideae were also well-represented. A clear prevalence of swamp forest plants with representatives of Taxodiaceae-Cupressaceae and

the Polypodiaceae in the undergrowth was noted. A significant increase of the swamp forests suggests a gradual swamping of this area after the regression of the sea. The taxa of Palaeotropical elements have been represented by less than 24.0%, however, the Arctotertiary palaeofloristical elements were dominated and they reached approximately of 75.0%. At that time the climate was subtropical changing into a warm-temperate (Figs. 15, 16).

In the Pomeranian Lakeland, the contact with the sea was completely disrupted at the end of the Late Oligocene and terrestrial facies prevail. A distinct change in the composition of plant communities was related to lignite producing cycles. At that time, it was possible to investigate some phases of the development of the peatbogs, however, they did not form a continuous successive cycles. The pollen spectrum of lignite sections in this part of the profile showed the domination of swamp forest, which gradually was changing into a peatbog, and successively being covered by shrubs of Cyrillaceae-Clethraceae, Myricaceae, *Ilex*, Ericaceae and Oleaceae due to the lowering of the water level.

In Neogene during formation of the II Łużyce Lignite Seam prevailed favourable conditions for the formation of swamps, and coal-bearing peatbogs. In this part of Miocene in the Łosiny 2/KB profile, two phases of the development of the plant communities have been distinguished. The recognized phases pointed to different habitats due to different composition of the dominating communities.

Phase F has been distinguished in the spectra of the II Łużyce Lignite Seam, comprising its older part — the lower seam of the Łosiny profile 2/KB (Fig. 12), but was also recognized in the spectra which were correlated with the profiles of: Tuchola-Białowieża VI (Fig. 13), Wymysłowo XI, Kamień 2/Ka and Gostycyn IV (Fig. 14). The dominant plant communities of the mixed mesophilous forest, in which numerous thermophilous taxa occurred were represented by the Fagaceae and the subfamily of Quercoideae, Castaneoideae and Juglandaceae with the *Engelhardtia*, *Platycarya*, *Platanus* and *Symplocos* as well as the sporadically palms occurred. The Lygodiaceae, Cyatheaaceae, Gleicheniaceae, which occurred in undergrowth of the forest, were represented by the ferns. In the process of formation of the coal-producing biomass the most important role has been played by shrubs, which reached up to 30.0% of Cyrillaceae-Clethraceae, Myricaceae, Ericaceae and *Ilex*. With the development of swamps in the lowermost part of the II Łużyce Lignite Seam, a replacement of the brushwood communities invading the peatbogs can be noticed. The above-mentioned cycle could be entirely investigated in the Łosiny 2/KB profile (Fig. 12). In this profile was noticed a characteristic and significant increase of Palaeotropical geoflora, especially of the subtropical element which reached up to 58.0%. At that time the climate was humid and warm, probably subtropical which favoured a coal-producing biomass (Figs. 15, 16).

Phase G has been distinguished in the plant communities which occurred in the younger upper part of the II Łużyce Lignite Seam in the Łosiny profile 2/KB (Fig. 12). Still, the mixed mesophilous forest dominated, while in comparison to the former phase, the significance of coniferous forest increased with a higher amount of *Pinus*. Among the deciduous mesophilous

forest elements of smaller thermal requirements were abundant and in the forest there occurred rich elements, which preferred a bigger humidity of the substratum. The plants which became more significant, and compared with contemporary genera were represented by: *Quercus*, *Fagus*, *Carpinus*, *Liquidambar*, *Betula* and *Fraxinus*. Less numerous were taxa of an unknown botanical affinity. Moreover, due to a rise of water level, this area was flooded, thus the role of the swamp forest elements such as *Taxodium*, *Nyssa*, *Alnus* and peatbogs with *Sphagnum* has increased. Less common were also the brushwood elements. The elements of Arctotertiary geofloras increased in

phase G. The climate of this phase may be defined as warm-temperate (Figs. 15, 16).

Phase H has been distinguished in the spectra of sediments related to sedimentation the IIA Lubin Lignite Seam in the Komorza 1/KB (Fig. 11) and Łosiny 2/KB profiles (Fig. 12), which were correlated with the other profiles of Raciąż II, Obrowo III, Piła Młyn V and Łyskowo PG 1. The low frequency and poor preservation state of the sporomorphs in phase H, prove that the sediments which contain the sporomorphs were dried periodically. Composition of mesophilous forest has been changed due to a further decrease of thermophilous elements.

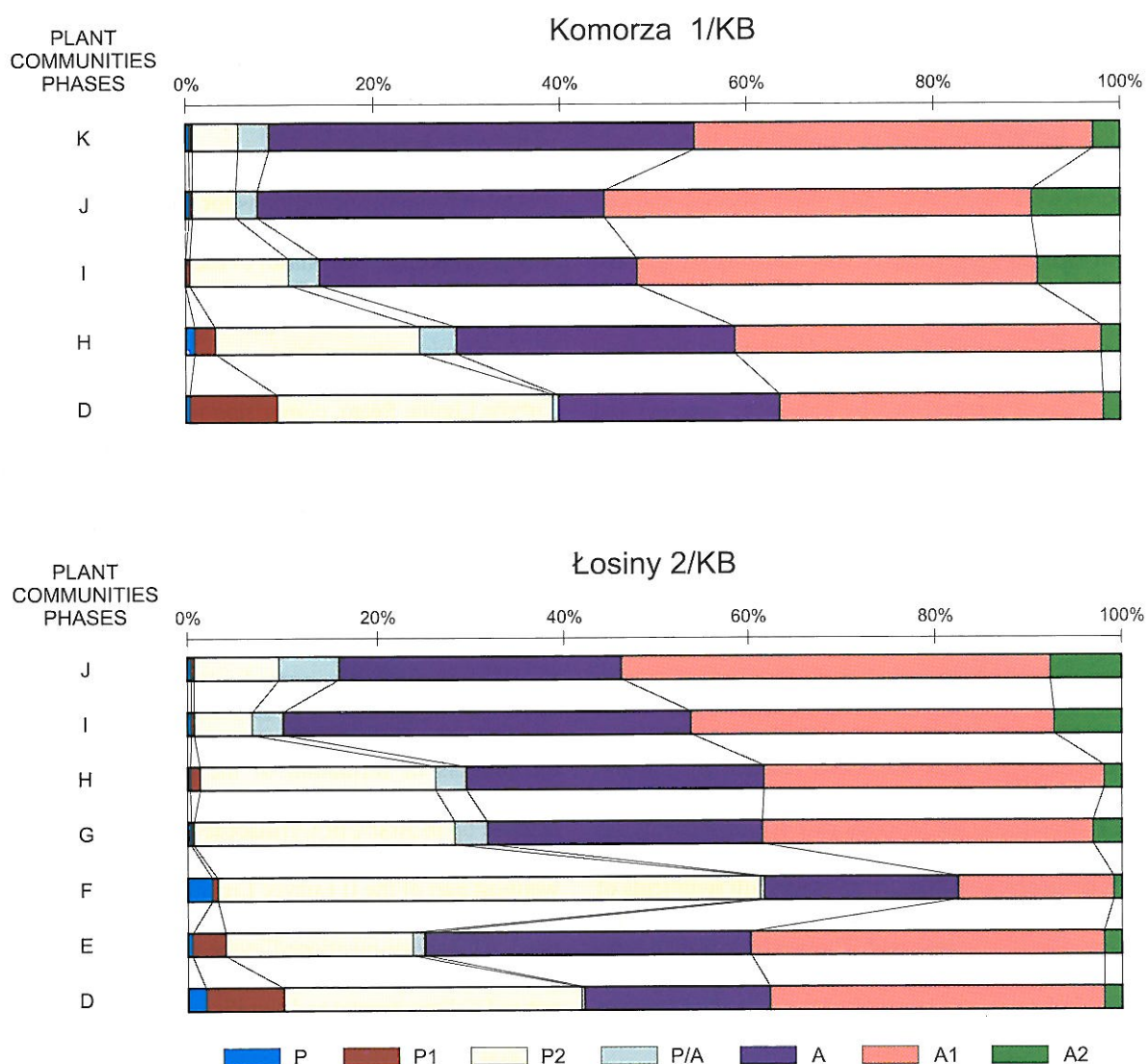


Fig. 16. Participation of the geofloristic elements in the phases of plant communities in Komorza 1/KB and Łosiny 2/KB boreholes

P — generally Palaeotropical element, P1 — tropical element, P2 — subtropical element; A — generally Arctotertiary element, A1 — warm-temperate element, A2 — cool-temperate element

Sporadically, occurred *Engelhardtia* as well as plants represented by Fagaceae. In the forest trees of temperate thermal requirements represented by *Quercus*, *Betula*, *Liquidambar*, *Fagus* and *Fraxinus* formed the dominant element. The important were the elements of coniferous forest, which reached up to 29.0%. Moreover, a clearer role was played by the representatives of brushwood elements up to 24.0% such as Cyrillaceae-Clethraceae, Myricaceae, Ericaceae, Caprifoliaceae and *Ilex* as well as the swamp forest up to 22.0% represented by *Taxodium*, *Nyssa*, *Alnus* and *Sphagnum* in the undergrowth. A further progressing increase of Arctotertiary geoflora elements has also been noticed. Character of the above mentioned communities suggest a warm-temperate climate (Fig. 15, 16).

Phase I has been found in the spectra of Komorza 1/KB (Fig. 11) and Łosiny 2/KB profiles (Fig. 12). After a successive culmination of the swamps, the sandy sedimentation began to cover the peatbogs and so a mineral sedimentation developed. Changes in the character of the sedimentation were caused by external factors probably such as cooling, aridity and the lowering of the erosion basis. In the mixed mesophilous forest communities has been noted a considerable increase of coniferous plants such as: *Pinus*, *Sequoia* and *Tsuga* which reached up to 45.0%. Moreover, the occurrence of small quantities of trees with the temperate thermal requirements such as: *Quercus*, *Fagus* and *Betula* have also been noted. A greater share has the elements of riparian forest represented by: *Ulmus*, *Pterocarya*, *Liquidambar*, *Fraxinus* as well as in a small quantity occurred the swamp forest elements such as: Taxodiaceae, *Nyssa* and *Alnus*. In the undergrowth were met the ferns of Polypodiaceae and peat mosses belonging to *Sphagnum*. Occurrence of the brushwood such as Ericaceae, Cyrillaceae, Caprifoliaceae and *Ilex* has been noted, as well. Considerable decrease of the palaeotropical elements up to 11.0% has been also observed. The climate cooled up and can be defined as warm-temperate, rather cooler than in phase H (Fig. 15, 16).

Phase J defined a stage of development of swamps during the formation of the I Middle Polish Lignite Seam. It has been established on the basis of the spectra from Komorza 1/KB (Fig. 11) and Łosiny 2/KB (Fig. 12) profiles, as well as supplemented by the data of Jeleń IV and Gostycyn IV profiles (Fig. 14). In the mixed forest community, an increase of the temperate forest was clearly marked by: *Quercus*, *Fagus*, *Betula* and *Carpinus*. Moreover, a role of riparian forest elements represented by *Pterocarya*, *Liquidambar*, *Carya* and *Ulmus* has also increased. A great amount of *Celtis* occurred, as well. Sporadically, were found termophilous plants of the *Engelhardtia* and Fagaceae

families. A coniferous forest comprised numerous trees such as: *Pinus*, *Abies*, *Sequoia* and *Sciadopitys*. The nature of swamp forest elements was clearly marked by the occurrence of: *Nyssa*, *Alnus* and Taxodiaceae-Cupressaceae as well as the occurrence of *Osmunda*, Polypodiaceae and *Sphagnum* in the undergrowth. Brushwood community composed of Ericaceae, Cyrillaceae, Rosaceae, Myricaceae, Caprifoliaceae, *Ilex*, *Vitis*, *Lonicera* and *Diervilla* showed a slight significance. For the first time in Neogene the number of herbaceous plants of open communities reached up to 3.0% and were represented by: *Polygonum*, Asteraceae, Oenotheraceae and Poaceae. Moreover, aquatic and swamp plants reached up to 5.0% and were abundantly represented by *Butomus*, *Myriophyllum*, *Trapa*, Sparganiaceae, Cyperaceae and Lythraceae. Similarly as in the previous phase, the Arctotertiary geoflora elements amounted to 85.0% of the flora (Fig. 15).

A certain differentiation of the communities within the phase J was seen in the Komorza 1/KB and Łosiny 2/KB profiles. In the Łosiny 2/KB profile most numerous were elements of mixed temperate forest with taxa similar to the Recent plants, whereas Komorza 1/KB profile swamp forest elements played a bigger role. Most probably, this may have resulted from differences in the substratum humidity. Plants of the temperate-warm and humid climates played an essential role during the formation of the I Middle Polish Lignite Seam.

Phase K characterises the final coal-producing stage, found in the sediments of the IA Oczkowice Lignite Seam in the Komorza 1/KB (Fig. 11), Mędomierz V and Piła-Młyn V profiles in the studied area. The coniferous forest, which reached up to 37.0%, and was represented, by *Pinus*, *Sequoia* and *Tsuga* was the most significant. Also, very important was the share of riparian forest reaching up to 20.0% with such genera as: *Ulmus*, *Fraxinus*, *Pterocarya*, *Celtis* and *Liquidambar*, as well as the swamp forest amounting to 20.0%, represented by *Alnus*, *Nyssa* and Taxodiaceae-Cupressaceae. Ferns of the family Polypodiaceae and peatbogs of the *Sphagnum* have occurred in the undergrowth. Mixed forest was represented by a small amount of *Betula*, *Quercus*, *Fagus* and *Acer*. Plants of the higher thermal requirements occurred rarely and were represented by shrubs. A share of herbaceous plants such as *Polygonum*, Poaceae, Apiaceae, Asteraceae, and Oenotheraceae as well as sedge-aquatic communities of *Butomus*, *Nuphar*, *Typha* and Sparganiaceae was clearly marked. The Arctotertiary geofloristical taxa had a dominant share reaching up to 91.0%. The climate of that time may be defined as temperate and humid (Figs. 15, 16).

PALYNOSTRATIGRAPHY OF THE PALEOGENE AND NEOGENE DEPOSITS BASED ON SPORES AND POLLEN ANALYSIS

Changes in the taxonomic composition and the percentage frequency of sporomorphs are closely related to climatic changes. Criteria of the stratigraphical subdivision based on palynostratigraphical studies have the features characteristic for climatostratigraphy (Krutzsch, 1967; Krutzsch, Majewski, 1967; Raniecka-Bobrowska, 1970; Ziemińska-Tworzydło,

1974; Sadowska, 1977). The stratigraphical subdivisions proposed by the above mentioned authors could be mainly applied to terrestrial Neogene deposits, where the lack of microfauna makes impossible the dating related to stratotypes of marine deposits. Thus, the distinguished spore-pollen assemblages are the basis for biostratigraphical dating of the terrestrial deposits.

Palynostratigraphy of the Paleogene deposits is mainly based on marine phytoplankton. Less precise investigation results of the Paleogene deposits are based on spore-pollen assemblages. Pollen material which is deposited in the marine sediments is generally very well-selected, and its composition depends on the following factors such as: distance from the coast, contents of terrestrial plant communities as well as fraction of deposits in which pollen are preserved. Climatic oscillations, which were marked in pollen spectra of marine assemblages, are more difficult to be defined.

In Neogene, the pollen spectra were quantitatively similar, thus for palynostratigraphical aims the very important were qualitative data about the occurring taxa. Proportions between the elements of the Palaeotropical and Arctotertiary geofloras and their relationship with Recent plant communities have a great importance. Isolation of spore-pollen assemblages, which have a stratigraphical significance from those, which have only habitat significance is also very important.

For particular lignite seams or units of higher lithostratigraphical rank such as (formation, member), the assignation of characteristic pollen assemblages has been performed (Ziemińska-Tworzydło, Ważyńska 1981; Piwocki, Ziemińska-Tworzydło, 1995, 1997; Słodkowska, 1998a). These assemblages have a rank of spore-pollen zones and they have been correlated with the lithostatigraphical subdivision of the Polish Lowland (Piwocki, 1998; Ziemińska-Tworzydło, 1998). The separated palynological assemblages from all the profiles of the Tuchola region have been correlated with palynostratigraphical, lithostratigraphical and chronostratigraphical subdivisions and illustrated on the table (Table 10). They have been also marked in the palynostratigraphical compilation of profiles from the Tuchola region (Fig. 2).

THE PRE-PALEOGENE BASEMENT

An age of the Paleogene basement in the studied area is based on the Early Cretaceous spore-pollen assemblages in the Gronowo 2, Gronowo 3 and Myśligoszcz 1 boreholes. The main palynostratigraphical criterion was e.g. an occurrence of characteristic spores such as: *Concavisporites punctatus*, *Cingulatisporites valdensis*, *Lygodium giberrulum*, *Gleichenioidites* as well as the lack of angiospermes pollen (Mamczar, 1963). Moreover, in the Wilcze IG 1 borehole on the basis of the index spores, the lack of the angiospermes pollen, as well as on the occurrence of the characteristic phytoplankton the recognized assemblage is of the Lower Cretaceous age (Grabowska, 1985).

PALEOCENE

The Early Paleocene spore-pollen assemblages have not been recognized within the analysed profiles of the studied area.

The Middle Paleocene sporomorph assemblage has been recognized in the Komorza 1/KB (Figs. 2, 11; Table 10), at a depth of 203.22–248.00 m and the Łosiny 2/KB (Fig. 2, 12; Table 10) at a depth of 192.63 m (phase A). A very characteristic

feature of this assemblage was the species richness and a large amount of marine phytoplankton as well as the occurrence of Normapolles group with 14 species among which occurred: *Nudopollis* represented by the three species — *N. thiergartii*, *N. minutus* and *N. endangulatus*, as well as *Oculopollis concentus*, *Interpollis*, *Longanulipollis* cf. *capsula*, *Stephanopora-pollenites*, and *Trudopollis* represented by the two species of *Trudopollis* sp., *T. cf. bulboformis*, *Semioculopollis* sp. A, *Vacuopollis semiconcavus* and *Extratropipollenites parmutus*. On the basis of phytoplankton, this part of the profile was precisely dated on the Middle Paleocene — Selandian related to the Odra Formation.

EOCENE

In the analysed profiles of the studied area the Early Eocene and Middle Eocene assemblages have not been found.

The Late Eocene spore-pollen assemblage (phase B) has been found only in the Obrowo III profile (Fig. 2; Table 10). This assemblage was very rich in Palaeotropical taxa of Normapolles group. *Trudopollis* terminates its occurrence in the Upper Eocene. Pollen grains were accompanied by marine phytoplankton, dating this part of the profile on the Late Eocene age, which was lithostratigraphically related to the Pomorze Formation.

UPPER EOCENE/LOWER OLIGOCENE

Spore-pollen assemblage of the Late Eocene/Early Oligocene (phase C) has been established in the following profiles: Kłodawa 4/Kł, Kłodawa 5/Kł (Ważyńska, 1987), Kamień 1/KA and Mędromierz V (Fig. 2; Table 10). The pollen spectra consist of taxa, which were occurring through the whole Paleogene as well as in the lower part of Neogene. These spectra together with phytoplankton composition contained the index taxa, which have transitional character between the Late Eocene/Early Oligocene. Lithostratigraphically, this assemblage belongs to the Lower Mosina Formation and may be correlated with similar assemblages known from the northern part of Poland (Grabowska, 1987; Grabowska, Ważyńska, 1997).

OLIGOCENE

A stable and continuous correlative horizon in the Pomeranian Lakeland is Early Oligocene — Rupelian pollen assemblages (phase D), which has been distinguished in the 17 profiles of the studied area: Myśligoszcz 1, Gronowo 2, Gronowo 3 (Mamczar, 1963), Łysakowo PG 1 (Rębas, 1984), Wilcze IG 1 (Grabowska, 1985), Kłodawa 4/Kł, Kłodawa 5/Kł (Ważyńska, 1987b), Raciąż II, Komorza 1/KB (Fig. 11), Łosiny 2/KB, (Fig. 12) Tuchola-Białowieża VI (Fig. 13), Wymysłowo 11, Obrowo III, Jeleńcz IV, Kamień 2/KA, Piła-Młyn V and Gostyń IV (Figs. 12, 14; Table 10). For this spore-pollen spectrum of the phase D a very characteristic is an occurrence of index taxon of *Camarozonosporites heskemensis* as well as a high

amount of thermophilous angiosperm pollen of: *Fasuspollenites fusus*, *Castaneoideaepollis pusillus*, *C. oviformis*, *Dicolpopollis kockeli*, *Tricolporopollenites staresedloensis*, *T. quisqualis*, *Platanipollis ipelensis*, *Milfordia incerta*, *Quercoidites microhenrici*, *Intratropopollenites insculptus*, *Sapotaceoideaepollenites*, *Engelhardtioipollenites quietus*. Moreover, occur the index taxa such as: *Aglaeoreidiapollis cyclops*, *Boehlensipollis hohli*, *Cupanieidites eucalyptoides*. The index fossil taxa for this assemblage is also phytoplankton. The Early Oligocene spore-pollen and phytoplankton spectra should be related to widely distributed assemblages, which have been distinguished from the Czempe Formation in the Polish Lowland (Grabowska, 1965, 1987; Grabowska, Piwocki, 1975; Słodkowska, 1995; Grabowska, Ważyńska, 1997).

Late Oligocene palynomorph assemblage (**phases E**) has been found in the Łosiny 2/KB (Figs. 2, 12; Table 10) and Mędomierz V profiles (Fig. 2; Table 10). Occurrence of the characteristic spores of the *Verrucatosporites balticus balticus* and the pollen grains of plants which were more often met in Paleogene than in Neogene as well as sporadic specimens of Paleogene phytoplankton additionally points to the Late Oligocene (Chattian) age of this assemblage which is characteristic for the lithostratigraphical Upper Mosina Formation. The closely related spectra have been recognized from the profile in the Toruń — Brachnowo vicinity (Grabowska, 1970b; Grabowska, Piwocki, 1975).

MIDDLE MIOCENE

The oldest palynologically dated pollen assemblages from Neogene deposits in the studied area belonged to the II Łużyce Lignite Seam. They form a regularly occurring correlative horizon with a stable palynological content (Słodkowska, 1998a). The dominant are spores and pollen grains of the thermophilous plants, which derived from the peatbog communities, shrubs as well as swamp and mixed mesophilous forests. In the profiles of Tuchola region, in the II Łużyce Lignite Seam three horizons have been recognized and they are related to phases of the dominant plant communities. In the Łosiny 2/KB profile within the II Łużyce Lignite Seam, have been distinguished two clearly seen zones based on the pollen succession. Common species for the both zones are *Quercoidites henrici* and *Tricolporopollenites pseudocingulum* which have a stratigraphical significance enable to include the both zones to the II Łużyce Lignite Seam.

The oldest Neogene spore-pollen assemblage (**phase F**) defines the II Łużyce Lignite Seam and has been established in the Łosiny 2/KB (Figs. 2, 12; Table 10), Tuchola-Białowieża VI (Figs. 2, 13; Table 10), Gostycyn IV (Figs. 2, 14; Table 10) and Kamień 2/KA (Fig. 2; Table 10) profiles. The most characteristic feature of this assemblage, apart from the numerous share of two index species *Tricolporopollenites pseudocingulum* and *Quercoidites henrici* is also the occurrence of palaeotropical elements such as *Engelhardtioipollenites quietus*, *Symplocoipollenites*, *Tricolporopollenites dolium*, *T. megaexactus*, *T. bruhlensis*, *T. exactus*, and *Myricipites rurensis*. The spore taxa such as: *Leiotriletes* and *Neogenisporites neogenicus* have been recognized.

The overlying pollen assemblages (**phase G**) in the II Łużyce Lignite Seam have been distinguished in the Łosiny 2/KB profile (Figs. 2, 12; Table 10). The very important element was also *Tricolporopollenites pseudocingulum* and *Quercoidites henrici*, but a share of thermophilous elements of the mixed mesophilous forest has been substantially decreased. The numerous taxa occurring in this assemblage are related to mixed forest trees such as *Quercoidites*, *Betulaepollenites betuloides*, *Liquidambarpollenites* as well as others. The pollen of swamp forest such as *Nyssapollenites* and *Alnipollenites verus* as well as pollen of the shrub communities such as *Tricolporopollenites megaexactus* and *Ericipites* have also been distinguished.

The third pollen assemblage of the II Łużyce Lignite Seam (**phase F/G**) has been distinguished in the profiles of Łyskowo PG 1 (Rębas, 1984), Piła-Młyn V and Lisie Jamy XI (Fig. 2; Table 10). This assemblage has a transitional character because it contains the elements, which are common for the both mentioned zones. Characteristic feature of this assemblage is a high share of the *Tricolporopollenites pseudocingulum* and *Quercoidites henrici* as well as the occurrence of: *Engelhardtioipollenites punctatus*, *Tricolporopollenites megaexactus*, *T. exactus*, *Ericipites ericius*, *Myricipites rurensis*, *M. bituitus*, *Nyssapollenites* and others. This assemblage has not been univocally correlated with the above assigned plant assemblages.

According to stratigraphical criterion the assemblages assigned to the II Łużyce Lignite Seam should be placed within the Ścinawa/Krajenka Formation, in the lowermost part of the Middle Miocene in the V climatic phase — spore-pollen *Quercoidites henrici* Zone (Table 10). The II Łużyce Lignite Seam met on the whole Polish Lowland has been palynologically described by many authors (Ziemińska-Tworzydło, 1974; Sadowska, 1977; Stuchlik *et al.*, 1990; Ciuk, Grabowska, 1991; Kohlman-Adamska, 1993; Słodkowska, 1995).

The successive assemblage (**phase H**) has been distinguished above the II Łużyce Lignite Seam in the following boreholes: Łyskowo PG 1 (Rębas, 1984), Komorza 1/KB, Łosiny 2/KB, Raciaż II, Wymysłowo 11, Jeleń IV and Piła-Młyn V (Figs. 2, 11; Table 10). The thermophilous elements which occur here are not so numerous as in the assemblage of the II Łużyce Lignite Seam, however, they are still present in the spectra: *Tricolporopollenites pseudocingulum*, *Engelhardtioipollenites punctatus*, *Tricolporopollenites megaexactus*, *T. exactus* as well as *Quercoidites*, *Faguspollenites*, *Liquidambarpollenites*, *Betulaepollenites betuloides*, *Ericipites*, *Inaperturopollenites dubius* and *Nyssapollenites*. The above studied assemblage may be correlated with the VI climatic phase — spore-pollen *Tricolporopollenites megaexactus* Zone (Table 10), which is characteristic for the IIA Lubin Lignite Seam, occurring in the lower part of the Middle Miocene of the Pawłowie/Adamów Formation. Similar assemblages have been distinguished from the profiles of the south-western (Sadowska, 1977, 1985) and central parts of Poland (Kohlman-Adamska, 1993).

In the upper part of the Pawłowie/Adamów Formation the successive assemblage has been distinguished in the Komorza 1/KB (Figs. 2, 11; Table 10) and Łosiny 2/KB (Figs. 2, 12; Table 10) boreholes (**phase I**). Decrease of the pollen coming from the Palaeotropical plants with a simultaneous increase of the Arctotertiary element such as: *Faguspollenites*,

Betulaepollenites betuloides and *Ulmipollenites undulosus* has been observed in this assemblage. Occurrence of the *Tricolporopollenites pseudocingulum* has been also noted, but it does not reach a bigger percentage number. The spectrum should be placed in the VII climatic phase — spore-pollen *Iteapollis angustiporatus* Zone (Table 10), in spite of the lack of the index taxon. The VII zone occurs in the upper part of the Pawłowice/Adamów Formation. The similar pollen assemblages have been distinguished from the profiles of the south-western part of Poland (Raniecka-Bobrowska, 1970), and central Poland (Ziemińska-Tworzydło, 1974; Kohlman-Adamska, 1993; Słodkowska, 1995). In the Komorza 1/KB (Figs. 2, 11; Table 10), Łosiny 2/KB (Figs. 2, 12; Table 10), Jeleń IV (Fig. 2; Table 10) and Gostycyn IV (Figs. 2, 14; Table 10) profiles, the successive Middle Miocene assemblages have been found (phase J). The occurrence of the mixed forest pollen — *Quercoidites*, *Faguspollenites*, the riparian forest — *Ulmipollenites undulosus*, *Betulaepollenites betuloides*, *Pterocaryapollenites* and swamp forest — *Alnipollenites verus*, *Nyssapollenites* as well as shrubs with *Ericipites* has been noted. Also, the occurrence of the *Celtipollenites verus* has been recognized. Occurrence of herbaceous plants — *Graminidites* and aquatic plants has been noted, as well. The above studied assemblage documents the I Middle Polish Lignite Seam. The composition of this assemblage show the similarity with the VIII climatic phase belonging to the spore-pollen *Celtipollenites verus* Zone of the lowermost part of the Middle Miocene of Poznań Forma-

tion. The I Middle Polish Lignite Seam is a very good correlative horizon in the area of the Polish Lowland. It has been described from many localities of Central Poland (e.g. Ziemińska-Tworzydło, 1974; Kohlman-Adamska, 1993; Słodkowska, 1995), Konin areas (Mamczar, 1960; Sadowska, Giża, 1991) and from south-western Poland (Sadowska, 1977). The youngest Miocene assemblage (phase K) has been clearly seen in the Tuchola area in the following profiles: Komorza 1/KB, Mędromierz V, Jeleń IV and Piła-Młyn V (Figs. 2, 11; Table 10). The elements of the Palaeotropical geoflora have been sporadically met, while the Arctotertiary element with *Betulaepollenites betuloides*, *Ulmipollenites undulosus*, *Pterocaryapollenites* was dominant. A rich was pollen of the swamp forest such as *Alnipollenites verus* and *Nyssapollenites*. The above studied assemblage is typical for the IA Oczkowice Lignite Seam and may be correlated with the IX climatic phase of the spore-pollen *Tricolporopollenites pseudocingulum* Zone. The species, which gave the name of this zone, occurs sporadically in the studied assemblage. According to the lithostratigraphical subdivision the above-mentioned assemblage could be included into the Middle Miocene part of the Poznań Formation. Analogous spectra have been described from western and south-western part of Poland (Ziemińska-Tworzydło, 1974; Dyjor, Sadowska, 1977; Sadowska, 1977) as well as central Poland (Słodkowska, 2002). In the studied area the occurrence of spectra characteristic for a higher Neogene zones have not been recognized.

PALAEO GEOGRAPHICAL ASPECTS OF CLIMATIC AND PLANT COMMUNITIES CHANGES

A picture of the plant community succession within the analysed profiles points to a general climatic change during the Paleogene and Neogene.

In the Middle Paleocene sediments, developed in a facies of relatively deep marine basin (phase A), the reconstruction of the flora seems to be difficult. Although, it may be assumed that climate was subtropical, and favourable for the development of the Palaeotropical geoflora mainly of the mesophilous forest communities.

Throughout the Late Eocene there continued the process of sedimentation in the marine basin, on the shores of which Palaeotropical geoflora with a considerable part of subtropical elements was dominant (phase B), while the picture of the prevalent communities did not undergo any considerable change in comparison with the former phase.

On the threshold of the Late Eocene–Early Oligocene (phase C) the climate and the vegetation cover were similar to phase B. Along the sea shores of the slightly shallower marine basin, dominated the subtropical flora mainly composed of the mixed mesophilous forest elements.

The sediments of the Early Oligocene were widely spread in the studied area (phase D). The marine basin was not very deep. A great number of land sporomorphs mainly composed of richly vegetated, warmth loving plants of the mixed mesophilous forest managed to reach the marine basin. Elements of Palaeotropical geoflora have been clearly marked in

this community and reached up to 40%. Regression of the marine Paleogene basin took place in the Late Oligocene (phase E). Along the seashores the mixed, mesophilous forest was still dominant, but it was less differentiated than during the Early Oligocene. The number of taxa of Palaeotropical flora diminished, while Arctotertiary geoflora become dominant. The climate was now slightly cooler and changing from a warm-temperate to subtropical (Figs. 15, 16). The Late Oligocene plant communities differed from the Middle Paleocene ones, and become more similar to the Neogene plant communities. The phases defined in the Paleogene sediments (besides the Late Oligocene — phase E), have been characterized by relative stability, both in respect of climatic conditions and the plant communities. In the palynologically dated stages of Paleogene such as Selandian, Priabonian and Rupelian, where each lasted about 5 million years, the flora assemblage suggested the existence of a subtropical climate. These assemblages were composed of extinct taxa, which obviously grew in the mesophilous forest community and did not have contemporary equivalents. In the marine sediments of these periods, palynological assemblages, which could point to distinctive climatic oscillations and floristical changes, have not been noticed.

In the Neogene — Middle Miocene deposits, the sedimentation in terrestrial basins took place, and it was very often connected with an accumulation of lignite seams. The climatic and floristic changes were more precisely registered in this envi-

ronment. This is particularly shown in the changing domination of plant communities and geofloristical elements. An essential role during the development of plant communities was played by the humidity of substratum related to the oscillation of the ground waters. Moreover, distinct, cyclic climatic changes as well as coal-producing activity have also been registered.

In the lowermost part of the II Łużyce Lignite Seam has been noted the warmest, subtropical episode in the development of the Middle Miocene flora of this region (**phase F**) — Figs. 15, 16. The dominant role in this phase was performed by the Palaeotropical geoflora elements up to 62.0%, which occurred abundantly in the mesophilous forest reaching up to 37.0%. In the upper part of the II Łużyce Lignite Seam (**phase G**) has been noted a considerable decrease of the palaeotropical taxa, which did not amount to 28.0% (Figs. 15, 16). The climate at that time was warm-temperate. The dominant part of flora was formed by a mixed mesophilous forest, with a considerable increase of coniferous trees, which reached up to 27.0%. During the formation of the successive, IIA Lubin Lignite Seam (**phase H**), a further cooling of the climate was observed as well as an increase in Arctotertiary geofloristical elements (up to 70.0%), with a bigger share of coniferous forest (29.0%) see Figs. 15, 16 has been noted. Still the dominant was a warm-temperate climate. Above, in non-producing coal part of the profile (**phase I**) an amount of the Arctotertiary element became dominant up to 86.0%. A coniferous forest was dominant, reaching up to 45.0% in all the communities. It may suggest the progressing cooling and aridity of the climate, which did not favour the formation of swamps and the lignite seams. The next episode of the increasing humidity of climate was connected with sedimentation of the I Middle Polish Lignite Seam (**phase J**) — see Figs. 15, 16. Character of mesophilous forest communities has been changed considerably in which

the significance of warm temperate trees analogous to contemporary mixed forests increased. A great significance at that time had riparian and swamp forests. Still, the dominant were the elements of Arctotertiary geoflora. The climate was warm-temperate, but warmer and more humid than during the phase I. The IA Oczkowice Lignite Seam (**phase K**) terminated the palynologically documented sedimentation of the Miocene deposits (Figs. 15, 16). A great significance in the abovementioned phase had the flora of coniferous, riparian and swamp forest communities. While the Arctotertiary element was almost entirely dominant and reached up to 91.0%, the palaeotropical element occurred sporadically, and did not amount to 6.0%. The climate was temperate and warm.

The above-mentioned differences in the composition of the plant communities resulted from the changes of the climatic conditions. In the lower part of the Neogene profile, the dominant were communities, which evidenced an existence of subtropical climate with domination of mixed mesophilous forest of temperate humid habitats as well as with the abundance of the warmth-loving plants. The increasing humidity of the warm climate enabled the development of swamp forests and brushwood, which contributed to the formation of lignites. Towards the upper part of the profile during the formation of peatbogs, a significance of mixed and riparian forest communities of lower thermal requirements was increasing. This process was connected with progressing deterioration of the climate. Plant communities became poorer in Palaeotropical geoflora elements, and they were dominant for the last time, during the formation of the lower part of the II Łużyce Lignite Seam. A core of the flora was formed by Arctotertiary elements in the upper part of the Middle Miocene.

PALYNOLOGICAL MATTER IN THE SYNTHESIS SECTION OF MIOCENE DEPOSITS FROM THE POMERANIAN LAKE LAND

The Paleogene marine sedimentary cycle was followed by Miocene continental, freshwater deposition, as evidenced from the upper part of the section. It was well reflected in the palynomorphs composition. No marine phytoplankton occurs in the Miocene deposits. Spores and pollen grains of continental plants were of fundamental significance, and their diversity indicated luxuriant vegetation.

Some general rules concerning the composition of sporomorph assemblages have been seen. In the Miocene parts of the profile, connected with a swamp environment, angiosperms and non-saccate gymnosperms predominated over the saccate gymnosperms and spores. This results from the fact, that in a swamp basin the short-range local flora is the most important. In a terrestrial basin, of an open lake, saccate gymnosperms prevail over angiosperms, since in this case pollen travelling over a long distance has greater significance (Table 11). Phytoplankton, which occurred in the Miocene terrestrial facies, consists of colonial Chlorophyta,

are rarely found, whereas the freshwater-unicellular, noncolonial Chlorophyta are more frequent. colonial Chlorophyta mainly occur in still waters of swamp basins (Fig. 7).

The composition of palynoclasts in the Miocene sediments suggested terrestrial sedimentation. The share of the terrestrial

Table 11

Sporomorphs in the studied material (Neogene)

Age	Sporomorphs	Environment
Middle Miocene	Angiosperms, Gymnosperms (nonsaccate) > Gymnosperms (saccate), Spores	Terrestrial — swamp
	Angiosperms > Gymnosperms (saccate + nonsaccate), Spores, Fungal spores	Terrestrial — lake

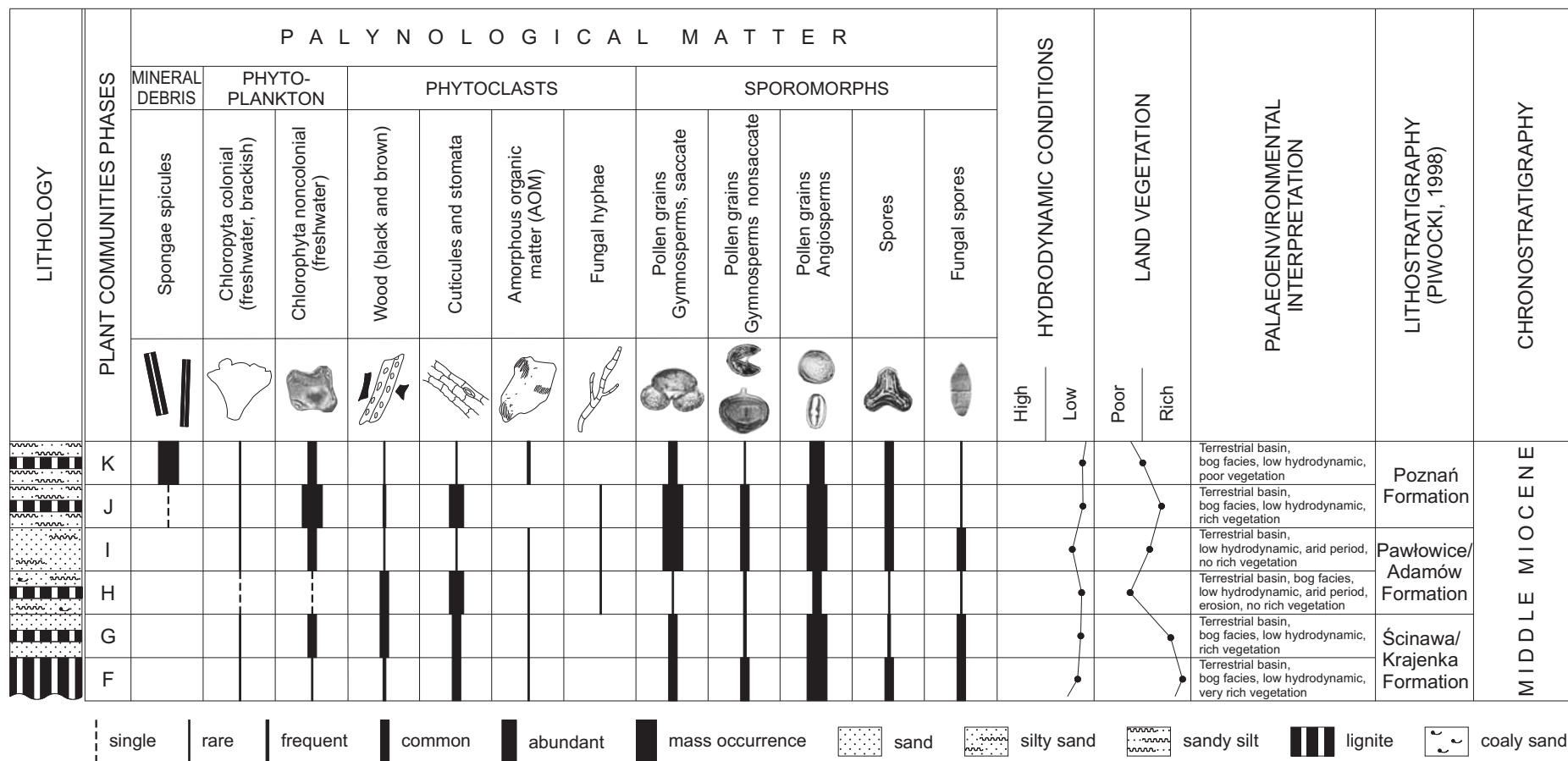


Fig. 17. Palynological matter in Neogene deposits of the Tuchola region

plant tissue in the Paleogene sediments increased in regard to the phytoclasts. The observation of the changes in the frequency of the phytoclast elements in the sediments proves the rule that during the lignite sedimentation the participation of the wood debris, cuticles and separate fragments of amorphous organic matter was more significant which indicates the presence of a great amount of plant biomass. Thus, there are more phytoclasts in the sediment, whereas, in the clastic, clayey-silt sediments, phytoclasts occur sporadically, although they are always present in the assemblage of the palynological matter.

The analysis of the chronological occurrence of the particular components of the palynological matter elements makes possible to reconstruct the character of vegetation and the sedimentary conditions.

In the lowermost lignite seam (**phase F**), an abundant share of angiosperm pollen, which proves existence of plant vegetation, has been observed. It was mainly a swamp flora. The plants of the drier localities were less significant, because the long distance, travelling bisaccate pollen of coniferous trees occurred less abundantly. Most common, however, was the fungal spores, which show the existence of a rich floristically, matter. The above data prove optimal, and most favourable conditions for the development of coal-producing plants in the analysed profile (Fig. 17; Pl. XV).

In the upper part of this profile, as well as in coal-producing deposits (**phase G**), the change in the composition of the palynological matter was insignificant. Only, an amount of the freshwater, noncolonial Chlorophyta has increased. The number of phytoclasts was slightly bigger than in phase F, which may be attributed to a slight change of the environmental conditions, but the humidity of the substratum still favoured the richness of the flora (Fig. 17; Pl. XVI).

The bigger changes in the number of organic debris have been noted in the coal-bearing and sandy-silt parts of the profile (**phase H**). Phytoplankton represented by noncolonial and colonial Chlorophyta, sporadically occurred; thus the share of pollen also decreased considerably. The gymnosperm pollen occurred rarely, but the angiosperm pollen, which in the former phase mass occurred, now become common. Moreover, the number of the fungal spores decreased, as well. The phytoclasts, however, did not change their numbers and still mass occurred.

The above-mentioned scheme of the palynological matter picture points to a change in the character of sedimentation. The poor preservation state of the palynomorphs and their low frequency may suggest a periodical aridity and an erosional process of the studied sediments (Fig. 17; Pl. XVII).

A richer assemblage of palynological matter comes from the sandy sediments in the higher part of the profile (**phase I**). Once again, the freshwater, noncolonial Chlorophyta occurred commonly while the colonial ones occurred less abundantly. The spores of the terrestrial flora occurred abundantly, fungal spores, mosses and ferns also were numerous, while phytoclasts were less common. The character of the deposits as well as the contents of the palynological matter may suggest the sedimentation in a relatively high-energy environment, which did not favour the deposition of a rich organic matter and the formation of peatbogs. This type of sedimentation may have occurred in a basin of a higher flow (peat-fen) on an alluvial plain or in an inland delta (Fig. 17; Pl. XVIII).

During the deposition of successive coal-sand sediments (**phase J**), the existent environmental conditions favoured rich flora vegetation. Both the freshwater, noncolonial Chlorophyta and the pollen occurred en mass. Mosses and ferns spores occur abundantly, while the share of fungal spores considerably decreased. Moreover, phytoclasts, especially, cuticles and numerous fragments of wood occurred in abundance. Sedimentation took again place in a terrestrial, low-energy basin (Fig. 17; Pl. XIX).

Lignite and sandy sediments constituted the higher part of the profile (**phase K**). The content of all the organic debris has decreased. Both groups of the Chlorophyta were less abundant, although the freshwater, noncolonial ones were still common. Among the terrestrial debris the pollen of angiosperms, occurred in abundance and the spores, were quite common, but the phytoclasts occurred more rarely. Within the phytoclasts, however, the amorphous organic matter was often noticed. There, appeared masses of sponge spicules, probably reworked and carried into the sediments. The above-presented data suggest the existence of sedimentation conditions in a basin of relatively moderate low water flows, similar to those conditions, which usually occur in a peat-fen (Fig. 17; Pl. XX).

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Phytoplankton from Paleogene deposits of Tuchola region

Taxa	Phytoplankton group	Environment, predominant facies, distance from land, salinity, temperature
<i>Achomosphaera</i> Evitt, 1963	Dg	marine, outer shelf, transgressive episode, warm water
<i>Achomosphaera alcornu</i> (Eisenack, 1954) Davey & Williams, 1966	Dg	marine, outer shelf, transgressive episode, cool water
<i>Achomosphaera crassipellis</i> (Deflandre & Cookson, 1955) Stover & Evitt, 1978	Dg	marine, outer shelf, transgressive episode, cool water
<i>Alisocysta</i> sp. 1 Heilmann-Clausen, 1985	Dg	marine, warm water
cf. <i>Alterbidinium</i> Lentin & Williams, 1985	Dp	marine
<i>Alterbidinium circumum</i> (Heilmann-Clausen, 1985) Lentin & Williams, 1989	Dp	marine
<i>Apectodinium homomorphum</i> (Deflandre & Cookson, 1955) Lentin & Williams, 1977	Dp	marine, costal, low salinity
<i>Apectodinium summisum</i> (Harland, 1979) Lentin & Williams, 1981	Dp	costal marine, inner shelf, brackish water, low salinity
<i>Apteodinium</i> Eisenack, 1958	Dg	marine,
<i>Areoligera coronata</i> (Wetzel, 1933) Lejeune-Carpentier, 1938	Dg	marine, outer shelf, high energy
<i>Areoligera senonensis</i> Lejeune-Carpentier, 1938	Dg	marine, outer shelf
<i>Areoligera</i> cf. <i>senonensis</i> Lejeune-Carpentier, 1938	Dg	marine, outer shelf
<i>Botryococcus brauni</i> Kützing	Chm	marine, brackish
<i>Caligodinium</i> Drugg, 1970	Dg	marine, inner shelf, estuary, normal and low salinity
<i>Caligodinium aceras</i> (Manum & Cookson, 1964) Lentin & Williams, 1973	Dg	marine
<i>Cerodinium</i> cf. <i>dartmoorium</i> (Cookson & Eisenack, 1965) Lentin & Williams, 1987	Dp	marine, shallow
<i>Cerodinium depressum</i> (Morgenroth, 1966) Lentin & Williams, 1987	Dp	marine, shallow
<i>Cerodinium diebelii</i> (Alberti, 1959) Lentin & Williams, 1987	Dp	marine, shallow
<i>Cerodinium medcalfii</i> (Stover, 1974) Lentin & Williams, 1987	Dp	marine, inner shelf, normal and low salinity
<i>Cerodinium speciosum</i> (Alberti, 1959) Lentin & Williams, 1987	Dp	marine, shallow
<i>Cerodinium striatum</i> (Drugg, 1967) Lentin & Williams, 1987	Dp	marine, shallow
<i>Charlesdowniea</i> Lentin & Vozzhennikova, 1989	Dp	costal marine, inner shelf, brackish water
<i>Chiropteridium lobospinosum</i> (Gocht, 1956) Gocht, 1960	Dg	marine, shelf
<i>Chiropteridium partispinatum</i> (Gerlach, 1961) Brosius, 1963	Dg	marine, shelf
<i>Circulisporites</i> De Jersey, 1962	Chun	freshwater
<i>Circulisporites circulus</i> (Wolff 1934) Krutzsch & Pacltová, 1990	Chun	freshwater
<i>Cleistosphaeridium insolitum</i> (Eaton 1976) Stover & Evitt, 1978	Dg	marine, shelf, normal salinity
<i>Cordosphaeridium fibrospinosum</i> Davey & Williams, 1966	Dg	marine, outer shelf, transgressive facies, normal salinity
<i>Cordosphaeridium funiculatum</i> Morgenroth, 1966	Dg	marine, outer shelf
<i>Cordosphaeridium</i> cf. <i>funiculatum</i> Morgenroth, 1966	Dg	marine outer shelf
<i>Cordosphaeridium inodes</i> (Klumpp, 1953) Eisenack, 1963	Dg	marine, outer shelf
<i>Crassosphaera</i> Cookson & Manum, 1960	P	marine, shelf, brackish
<i>Cyclapophysis monmouthensis</i> Benson, 1976	P	marine, shelf, brackish

Appendix A continued

Taxa	Phytoplankton group	Environment, predominant facies, distance from land, salinity, temperature
<i>Cyclonephelium</i> (Deflandre & Cookson, 1955) Stover & Evitt, 1978	Dg	marine
<i>Cymatiosphaera bleawykensis</i> Wall, 1965	P	marine, shelf, brackish
<i>Cymatiosphaera bujakii</i> De Coninck, 1986	P	marine, shelf, brackish
<i>Cymatiosphaera</i> cf. <i>delicata</i> Cookson & Eisenack, 1971	P	marine, shelf, brackish
<i>Cymatiosphaera radiata</i> Wetzel, 1933	P	marine, shelf, brackish
<i>Cymatiosphaeropsis</i> Mädler, 1963	P	marine, shelf, brackish
<i>Cystidiopsis conicus</i> Grabowska, 1996	A	marine, shallow
<i>Cystidiopsis</i> cf. <i>conicus</i> Grabowska, 1996	A	marine, shallow
<i>Deflandrea</i> (Eisenack, 1938) Lentin & Williams, 1976	Dp	marine, inner shelf, estuary, normal and low salinity
<i>Deflandrea phosphoritica</i> Eisenack, 1938	Dp	marine, outer shelf, transgressive facies, cool water
<i>Deflandridium</i> cf. <i>stellarium</i> (Potonié, 1934) Grabowska, 1996	Ch ?	brackish, freshwater
<i>Diagonalites</i> Krutzsch & Pacltová, 1990	Chun	freshwater
<i>Diphyes colligerum</i> (Deflandre & Cookson, 1955) Cookson, 1965	Dg	marine
cf. <i>Distatodinium</i> Eaton, 1976	Dg	marine
<i>Distatodinium</i> cf. <i>ellipticum</i> (Cookson, 1965) Eaton, 1976	Dg	marine
cf. <i>Ellipsoidictyum</i> Klement, 1960	Dg	marine
<i>Enneadocysta pectiniformis</i> (Gerlach, 1961) Stover & Williams, 1995	Dg	marine, outer shelf, low salinity
<i>Fibradinium</i> Morgenroth, 1968	Dg	marine, outer shelf, warm water
<i>Fibradinium annetorpense</i> Morgenroth, 1968	Dg	marine, outer shelf, warm water
<i>Fromea</i> Cookson & Eisenack, 1958	A	marine
<i>Glaphyrocysta</i> Stover Evitt, 1978	Dg	marine, outer shelf, high energy, warm water
<i>Glaphyrocysta ordinata</i> (Williams & Downie, 1966) Stover & Evitt, 1978	Dg	marine, outer shelf, high energy, warm water
<i>Glaphyrocysta pastielsii</i> (Deflandre & Cookson, 1955) Lentin & Williams, 1987	Dg	marine, outer shelf, high energy, warm water
<i>Glaphyrocysta semitecta</i> (Bujak, 1980) Lentin & Williams, 1981	Dg	marine, cool water
<i>Homotryblum</i> Davey & Williams, 1966	Dg	marine, inner or/and outer shelf, warm water, high salinity
<i>Homotryblum tenuispinosum</i> Davey & Williams, 1966	Dg	marine, outer shelf, warm water,
<i>Hystrichokolpoma</i> Klumpp, 1953	Dg	marine
<i>Hystrichokolpoma cinctum</i> Klumpp, 1953	Dg	marine
<i>Hystrichokolpoma rigaudiae</i> Deflandre & Cookson, 1955	Dg	marine
<i>Hystrichosphaeridium tubiferum</i> (Ehrenberg, 1838) Deflandre, 1937; emend. Davey & Williams, 1966	Dg	marine, warm water
<i>Impagidinium</i> Stover & Evitt, 1978	Dg	marine, oceanic, cool water
<i>Isabelidinium</i> Lentin & Williams, 1977	Dp	marine
<i>Isabelidinium</i> ? <i>viborgense</i> Heilmann-Clausen, 1985	Dp	marine
<i>Kallosphaeridium</i> (De Coninck, 1969) Jan du Chêne, 1985	Dg	marine
<i>Leiosphaeridia</i> (Eisenack, 1958) Downie & Sarjeant, 1963	P	marine, shelf, brackish

Appendix A continued

Taxa	Phytoplankton group	Environment, predominant facies, distance from land, salinity, temperature
<i>Lejeunecysta</i> Artzner & Dörhöfer, 1978	Dp	marine
<i>Lingulodinium</i> (Wall, 1967) Wall & Dale, 1973	Dg	marine, shallow, normal salinity, warm water
<i>Lingulodinium machaerophorum</i> (Deflandre & Cookson, 1955) Wall, 1967	Dg	marine, shallow, normal salinity, warm water
<i>Lithosphaeridium</i> Davey & Williams, 1966	Dg	marine
<i>Megatetrapidites</i> Krutzsch & Pacltová, 1990	Chun	freshwater
<i>Megatetrapidites rhomboides</i> Krutzsch & Pacltová, 1990	Chun	freshwater
<i>Melitasphaeridium</i> Harland & Hill, 1979	Dg	marine
<i>Melitasphaeridium choanophorum</i> (Deflandre & Cookson, 1955) Harland & Hill, 1979	Dg	marine
<i>Membranophoridium aspinatum</i> Gerlach, 1961	Dg	marine, shelf
<i>Membranosphaera</i> (Samoilovich, 1961) Norris & Sarjeant, 1965	Dg	marine
<i>Michrystidium</i> (Deflandre, 1937) Sarjeant, 1966	A	marine, shallow, inner shelf, high energy, beginning and close of the transgression cycle
<i>Microdinium</i> (Cookson & Eisenack, 1960) Stover & Evitt, 1978	Dg	marine, outer shelf, warm water
<i>Microdinium</i> cf. <i>ornatum</i> Cookson & Eisenack, 1960	Dg	marine, outer shelf, warm water
<i>Microdinium reticulatum</i> Vozzhennikova, 1967	Dg	marine, outer shelf, warm water
<i>Oligosphaeridium</i> Dayey & Williams, 1966	Dg	marine, normal salinity
<i>Operculodinium</i> Wall, 1967	Dg	marine shelf, cool water
<i>Ovoidites ligneolus</i> (Potonié, 1951) Krutzsch, 1959	Chun	freshwater, inner shelf
<i>Palaeocystodinium-Andalusiella</i>	Dp	marine
<i>Palaeocystodinium australinum</i> (Cookson, 1965) Lentin & Williams, 1976	Dp	marine
<i>Palaeocystodinium denticulatum</i> Alberti, 1961	Dp	marine
<i>Palaeocystodinium</i> cf. <i>denticulatum</i> Alberti, 1961	Dp	marine
<i>Palaeocystodinium golzowense</i> Alberti, 1961	Dp	marine, cool water
<i>Palaeocystodinium</i> cf. <i>golzowense</i> Alberti, 1961	Dp	marine
<i>Palaeocystodinium lidiae</i> (Górka, 1963) Davey, 1969	Dp	marine
<i>Palaeoperidinium pyrophorum</i> (Ehrenberg, 1838) Sarjeant, 1967	Dp	marine
<i>Palambages morulosa</i> Wetzel, 1961	Chm	marine
<i>Paleotetradinium minusculum</i> (Alberti, 1961) Stover & Evitt, 1978	Dp	marine
<i>Paucilobimorpha incurvata</i> (Cookson & Eisenack, 1962) Präsl, 1994	A	marine
<i>Pediastrum</i> Meyen, 1829	Chm	freshwater, shelf, regressive facies
<i>Pentadinium laticinctum</i> Gerlach, 1961	Dg	marine
<i>Phanerodinium</i> cf. <i>carinatum</i> Below, 1987	Dg	marine
<i>Phanerodinium squamosum</i> Below, 1987	Dg	marine
<i>Phthanoperidinium</i> Drugg & Loeblich, 1967	Dp	marine, shallow, high or low salinity
<i>Phthanoperidinium amoenum</i> Drugg & Loeblich, 1967	Dp	marine, outer shelf
<i>Phthanoperidinium cernulatum</i> (De Coninck, 1975) Lentin & Williams, 1976	Dp	marine, shallow
<i>Pterospermella australiensis</i> (Deflandre & Cookson, 1955) Eisenack, Cramer & Diez, 1973	P	marine, shelf,

Appendix A continued

Taxa	Phytoplankton group	Environment, predominant facies, distance from land, salinity, temperature
<i>Rhombodinium freienwaldense</i> (Gocht, 1955) Grabowska, 1996	Dp	marine, inner shelf
<i>Rhombodinium longimanum</i> Vozzhennikova, 1967	Dp	marine, inner shelf
<i>Rhombodinium pustulosum</i> Châteauneuf, 1980	Dp	marine, inner shelf
<i>Rhombodinium</i> cf. <i>pustulosum</i> Châteauneuf, 1980	Dp	marine, inner shelf
<i>Sigmopolis</i> Hedlund, 1965	Chun	freshwater
<i>Sigmopolis pseudosetarius</i> (Weyland & Pflug, 1957) Krutzsch & Pacltová, 1990	Chun	freshwater
<i>Spinidinium clavum</i> Harland, 1973	Dp	marine
<i>Spinidinium densispinatum</i> Stanley, 1965	Dp	marine
<i>Spinidinium echinoideum</i> (Cookson & Eisenack, 1960) Lentin & Williams, 1976	Dp	marine
<i>Spiniferites</i> (Mantell, 1850) Sarjeant, 1970	Dg	marine, outer shelf, transgressive facies
<i>Spiniferites cornutus</i> (Gerlach, 1961) Sarjeant, 1970	Dg	marine, outer shelf, transgressive facies
<i>Spiniferites pseudofurcatus</i> (Klumpp, 1953) Sarjeant, 1970	Dg	marine, outer shelf, transgressive facies
<i>Spiniferites ramosus</i> (Ehrenberg, 1838) Mantell, 1854	Dg	marine, outer shelf, transgressive facies
<i>Spiniferites ramosus granosus</i> (Davey & Williams, 1966) Lentin & Williams, 1973	Dg	marine, outer shelf, transgressive facies
<i>Spinitetrapidites quadriformis</i> Krutzsch & Pacltová, 1990	Chun	freshwater
<i>Spinitetrapidites longicornutus</i> Krutzsch & Pacltová, 1990	Chun	freshwater
<i>Stigmozygodites</i> Krutzsch & Pacltová, 1990	Chun	freshwater
<i>Stigmozygodites multistigosus</i> (Potonié, 1931) Krutzsch & Pacltová, 1990	Chun	freshwater
<i>Systematophora</i> Klement, 1960	Dg	marine, outer shelf, warm water
<i>Tectatodinium</i> Wall, 1967	Dg	marine, outer shelf, cool water
<i>Tetrapidites</i> (Klaus, 1950) Meyer, 1956	Chun	freshwater
<i>Tetrapidites crassus</i> Krutzsch & Pacltová, 1990	Chun	freshwater
<i>Thalassiphora</i> (Eisenack & Gocht, 1960) Gocht, 1968	Dg	marine, outer shelf, euxinic condition
<i>Thalassiphora pelagica</i> (Eisenack, 1954) Eisenack & Gocht, 1960	Dg	marine, outer shelf, euxinic condition
<i>Veryhachium</i> Downie, Evitt & Sarjeant, 1963	A	marine, shallow, high energy
<i>Wetzeliiella</i> (Eisenack, 1938) Lentin & Williams, 1976	Dp	marine, inner shelf, brackish, low salinity
<i>Wetzeliiella articulata</i> Eisenack, 1938	Dp	marine, inner shelf, brackish, low salinity
<i>Wetzeliiella meckelfeldensis</i> Gocht, 1969	Dp	marine, inner shelf, brackish, low salinity
<i>Wetzeliiella symmetrica</i> Weiler, 1956	Dp	marine, inner shelf, brackish, low salinity
Acritarcha — non identified	A	marine
Dinoflagellata freshwater	Dp	freshwater, inner shelf

Phytoplankton groups:

Dg — gonyaulacoid dinocyst; Dp — peridinioid dinocyst; P — Prasinophyta; A — Acritarcha; Ch — Chlorophyta;
Chun — Chlorophyta unicellular, noncolonial, freshwater; Chm — Chlorophyta multicellular, colonial, brackish and freshwater

Pollen and spores from Paleogene and Neogene deposits of Tuchola region

Taxon, author	Botanical affinity	Plant communities element	Geofloristic element
SPORES			
<i>Azolla</i> — massula	Salviniaceae	aquatic communities	A1
<i>Baculatisporites</i> Pflug & Thomson, 1953	Osmundaceae	swamp forest	A1
<i>Baculatisporites nanus</i> (Wolff, 1934) Krutzsch, 1953	Osmundaceae, <i>Osmunda claytoniana</i> type	swamp forest	A1
<i>Baculatisporites primarius</i> (Wolff, 1934) Pflug & Thomson, 1953	Osmundaceae, <i>Osmunda</i> type	swamp forest	A1
<i>Camarozonosporites decorus</i> (Wolff, 1934) Krutzsch, 1963	Lycopodiaceae, <i>Lycopodiella</i> sect. <i>Campylostachys</i>	mesophilous forest	P1
<i>Camarozonosporites heskemensis</i> (Pflanzl, 1955) Krutzsch, 1959	Lycopodiaceae, <i>Lycopodiella</i> sect. <i>Campylostachys</i>	mesophilous forest	P1
<i>Cicatricosisporites</i> cf. <i>paradorogensis</i> Krutzsch, 1959	Lygodiaceae, Parkeriaceae, Dicksoniaceae	mesophilous forest	P1
<i>Cicatricosisporites paradorogensis</i> Krutzsch, 1959	Lygodiaceae, Parkeriaceae, Dicksoniaceae	mesophilous forest	P1
<i>Cicatricosisporites</i> cf. <i>chattensis</i> Krutzsch, 1961	Lygodiaceae, <i>Anemia</i> type	mesophilous forest	P2
<i>Cicatricosisporites dorogensis</i> Potonié & Gelletich, 1933	Lygodiaceae, Parkeriaceae, Dicksoniaceae	mesophilous forest	P1
<i>Concavisporites</i> Pflug, 1953	Gleicheniaceae	mesophilous forest	P
<i>Concavisporites</i> fsp. 4 Krutzsch, 1962	Gleicheniaceae	mesophilous forest	P1
<i>Corrugatisporites corruevallatus</i> (Krutzsch, 1967) Nagy, 1985	Lygodiaceae, <i>Lygodium</i> type	mesophilous forest	P2
<i>Corrugatisporites multivallatus</i> (Pflug, 1953) Planderová, 1990	Lygodiaceae, <i>Lygodium</i> type	mesophilous forest	P/A
<i>Cryptogrammasporis</i> Skawińska, 1994	Pteridaceae, <i>Cryptogramma</i> type	mesophilous forest	A1
<i>Distancoraesporis</i> (Krutzsch, 1963) Srivastava, 1973	Sphagnaceae, <i>Shagnum</i> type	swamp forest	A1
<i>Distancoraesporis ancoris</i> (Krutzsch, 1963) Srivastava, 1973	Sphagnaceae, <i>Shagnum</i> type	swamp forest	A1
<i>Distverrusporis</i> (Krutzsch, 1963) Jameossanaie, 1987	Sphagnaceae, <i>Shagnum</i> type	swamp forest	A1
<i>Distverrusporis electoides</i> (Krutzsch, 1963) Jansonius & Hills, 1987	Sphagnaceae, <i>Shagnum</i> type	swamp forest	A1
<i>Echinatisporis</i> Krutzsch, 1959	Selaginellaceae, <i>Selaginella</i> type	mesophilous forest	P/A
<i>Echinatisporis</i> cf. <i>cycloides</i> Krutzsch, 1963	Selaginellaceae, <i>Selaginella</i> type	mesophilous forest	P/A
<i>Echinatisporis echinoides</i> Krutzsch & Pacltová, 1963	Selaginellaceae, <i>Selaginella</i> type	mesophilous forest	P/A
<i>Echinatisporis embryonalis</i> Krutzsch, 1963	Selaginellaceae	mesophilous forest	P/A
<i>Echinatisporis longechinus</i> Krutzsch, 1959	Selaginellaceae, <i>Selaginella</i> type	mesophilous forest	P/A
<i>Echinatisporis</i> type <i>Selaginella vaginata</i>	Selaginellaceae, <i>Selaginella variegata</i> type	mesophilous forest	P/A
<i>Favoisporites trifavus</i> Krutzsch, 1959	Pteridaceae, Ophioglossaceae ?, Hymenophyllaceae ?	mesophilous forest	P/A
<i>Gleicheniidites</i> Ross, 1949	Gleicheniaceae	mesophilous forest	P1
<i>Hamulatisporis helenensis</i> (Krutzsch, 1963) Srivastava, 1975	Lycopodiaceae, <i>Lycopodiella</i> sect. <i>Caroliniana</i>	mesophilous forest	P/A
<i>Hamulatisporis rarus</i> (Doktorowicz-Hrebicka, 1960) Ważyńska, 2001	Lycopodiaceae, <i>Lycopodiella</i> sect. <i>Caroliniana</i>	mesophilous forest	P/A
<i>Laevigatosporites haardti</i> (Potonié & Venitz, 1934) Thomson & Pflug, 1953	Polypodiaceae	swamp forest	A
<i>Laevigatosporites nitidus</i> (Mamczar, 1960) Krutzsch, 1967	Davaliaceae, Polypodiaceae	swamp forest	A
<i>Leiotriletes</i> asp. <i>microsinusoides</i> Krutzsch, 1962	Lygodiaceae	mesophilous forest	P
<i>Leiotriletes</i> (Naumova, 1937) Potonié & Kremp, 1954	Lygodiaceae, Cyatheaceae ?	mesophilous forest	P
<i>Leiotriletes maxoides</i> Krutzsch, 1962	Lygodiaceae, <i>Lygodium</i> type	mesophilous forest	P

Appendix B continued

Taxon, author	Botanical affinity	Plant communities element	Geofloristic element
<i>Leiotriletes minor</i> (Krutzsch, 1962) Ziemińska-Tworzydło, 2001	Lygodiaceae, <i>Lygodium</i> type	mesophilous forest	P
<i>Leiotriletes neddenioides</i> Krutzsch, 1962	Lygodiaceae ?, Cyatheaceae ?	mesophilous forest	P
<i>Leiotriletes triangulatoideus</i> Krutzsch, 1962	Lygodiaceae, <i>Dicksonia</i> type	mesophilous forest	P
<i>Leiotriletes wolffii</i> Krutzsch, 1962	Lygodiaceae, <i>Lygodium</i> type	mesophilous forest	P
<i>Lusatisporis</i> Krutzsch, 1963	Selaginellaceae	mesophilous forest	A
<i>Lusatisporis</i> cf. <i>perinatus</i> Krutzsch, 1963	Selaginellaceae, <i>Selaginella sibirica</i> type	mesophilous forest	A
<i>Monoleiotriletes gracilis</i> Krutzsch, 1959	unknown		
<i>Neogenisporis</i> Krutzsch, 1962	Gleicheniaceae	mesophilous forest	P2
<i>Neogenisporis</i> cf. <i>plicatoides</i> Krutzsch, 1962	Gleicheniaceae	mesophilous forest	P2
<i>Neogenisporis</i> cf. <i>pseudoneddeni</i> (Krutzsch, 1959) Krutzsch, 1962	Gleicheniaceae	mesophilous forest	P
<i>Neogenisporis neogenicus</i> Krutzsch, 1962	Gleicheniaceae	mesophilous forest	P2
<i>Neogenisporis undulatus</i> Krutzsch, 1962	Gleicheniaceae	mesophilous forest	P
<i>Polypodiaceoisporites marxheimensis</i> (Mürriger & Pflug, 1952) Krutzsch, 1959	Schizeaceae ?, Disconiaceae ?, Pteridaceae ?, Cyatheaceae ?	swamp forest	P1
<i>Polypodiaceoisporites</i> Potonié, 1951 ex Potonie, 1956	Lygodiaceae, Dicksoniaceae, Polypodiaceae, Pteridaceae, Cyatheaceae	swamp forest	P1
<i>Radialisporis</i> Krutzsch, 1967	Lygodiaceae?, Parkeriaceae ?	mesophilous forest	P2
<i>Radialisporis radiatus</i> (Krutzsch, 1959) Jansonius & Hills, 1976	Lygodiaceae, <i>Anemia</i> type ?, <i>Mohria</i> type Parkeriaceae, <i>Ceratopteris</i> type ?	mesophilous forest	P2
<i>Reticulosporis gracilis</i> Krutzsch, 1967	Schizeaceae, <i>Schizaea</i> type	mesophilous forest	P1
<i>Reticulosporis polonicus</i> Krutzsch, 1959	Schizeaceae, <i>Schizaea pusilla</i> type	mesophilous forest	P1
<i>Retitriletes</i> Krutzsch, 1963	Lycopodiaceae	mesophilous forest	A1
<i>Retitriletes annotinioides</i> Krutzsch, 1963	Lycopodiaceae, <i>Lycopodium</i> sect. <i>Annotina</i>	mesophilous forest	A1
<i>Retitriletes bernheidensis</i> Krutzsch, 1963	Lycopodiaceae	mesophilous forest	A
<i>Retitriletes duplus</i> Krutzsch, 1963	Lycopodiaceae	mesophilous forest	A
<i>Retitriletes flaemingensis</i> Krutzsch, 1963	Lycopodiaceae	mesophilous forest	A
<i>Rudolphisporis rudolphi</i> (Krutzsch, 1959) Krutzsch & Pacltová, 1963	Anthocerotaceae	mesophilous forest	P/A
<i>Rugulatisporites quintus</i> Pflug & Thomson, 1953	Osmundaceae, <i>Osmunda regalis</i> type	swamp forest	A1
<i>Saxosporis brandenburgensis</i> Krutzsch, 1967	Anthocerotaceae	mesophilous forest	
<i>Stereigranisporis</i> (Krutzsch, 1963) Kedves, 1982	Sphagnaceae, <i>Sphagnum</i> type	swamp forest	A1
<i>Stereisporites</i> Pflug, 1953	Sphagnaceae, <i>Sphagnum</i> type	swamp forest	A1
<i>Stereisporites</i> (<i>Distancoaesporis</i> Krutzsch, 1963) <i>rueterbergensis</i> Krutzsch, 1963	Sphagnaceae, <i>Sphagnum</i> type	swamp forest	A1
<i>Stereisporites</i> (<i>Stereigranisporis</i> Krutzsch 1963) <i>semigranulus</i> Krutzsch, 1963	Sphagnaceae, <i>Sphagnum</i> type	swamp forest	A1
<i>Stereisporites cyclus</i> Krutzsch, 1963	Sphagnaceae, <i>Sphagnum</i> type	swamp forest	A1
<i>Stereisporites involutus</i> (Doktorowicz-Hrebicka, 1960) Krutzsch, 1963	Sphagnaceae, <i>Sphagnum</i> type	swamp forest	A1
<i>Stereisporites maximus</i> Krutzsch, 1963	Sphagnaceae, <i>Sphagnum</i> type	swamp forest	A1
<i>Stereisporites megastereis</i> Krutzsch, 1963	Sphagnaceae, <i>Sphagnum</i> type	swamp forest	A1
<i>Stereisporites minor</i> (Raatz, 1937) Krutzsch, 1959	Sphagnaceae, <i>Sphagnum</i> type	swamp forest	A1

Appendix B continued

Taxon, author	Botanical affinity	Plant communities element	Geofloristic element
<i>Stereisporites stereoides</i> (Potonié & Venitz, 1934) Thomson & Pflug, 1953	Shagnaceae, <i>Sphagnum</i> type	swamp forest	A1
<i>Stereisporites stictus</i> (Wolff 1934) Krutzsch, 1959	Sphagnaceae, <i>Sphagnum</i> type	swamp forest	A1
<i>Stereisporites validus</i> (Doktorowicz-Hrebicka, 1960) Grabowska, 2001	Sphagnaceae, <i>Sphagnum</i> type	swamp forest	A1
<i>Stereisporites welzowensis</i> Krutzsch, 1963	Sphagnaceae, <i>Sphagnum</i> type	swamp forest	A1
<i>Toroisporis</i> Krutzsch, 1959	Cyathaceae ?, Lygodiaceae	mesophilous forest	P1
<i>Triplanosporites</i> (Pflug, 1952) Thomson & Pflug, 1953	unknown	mesophilous forest	P
<i>Triplanosporites microsinuosus</i> Pflanzl, 1955	unknown	mesophilous forest	P
<i>Triplanosporites sinomaxoides</i> Krutzsch, 1962	unknown	mesophilous forest	P
<i>Triplanosporites sinuosus</i> (Pflug, 1952) Thomson & Pflug, 1953	unknown	mesophilous forest	P
<i>Verrucatosporites</i> Pflug & Thomson, 1953	Polypodiaceae, Davaliaceae	mesophilous forest	P2
<i>Verrucatosporites alienus</i> (Potonié, 1931) Thomson & Pflug, 1953	Davaliaceae, <i>Davalia</i> type	mesophilous forest	P2
<i>Verrucatosporites balticus</i> (Krutzsch, 1962) Krutzsch, 1967	Davaliaceae, Polypodiaceae, <i>Polypodium</i> type	mesophilous forest	P/A
<i>Verrucatosporites favus</i> (Potonié, 1931) Thomson & Pflug, 1953	Dennstaedtiaceae, <i>Paesia</i> type	mesophilous forest	P2
<i>Verrucatosporites histiopteroides</i> Krutzsch, 1962	Dennstaedtiaceae, <i>Histiopteris</i> type	mesophilous forest	P2
<i>Verrucatosporites megabalticus</i> Krutzsch, 1967	Davaliaceae, Polypodiaceae, <i>Polypodium</i> type	mesophilous forest	P/A
GYMNOSPERMS			
<i>Distachyapites tertiarus</i> (Krutzsch, 1962) Grabowska & Ważyńska, 2002	Ephedraceae, <i>Ephedra distachya</i> type	coniferous forest	
<i>Abiespollenites</i> Thiergart, 1937	Pinaceae, <i>Abies</i> type	coniferous forest	A2
<i>Abietinaepollenites microalatus</i> Potonié, 1931	Pinaceae, <i>Cathaya</i> type, <i>Pinus</i> type	coniferous forest	A1
<i>Cedripites</i> Wodehouse, 1933	Pinaceae, <i>Cedrus</i> type	coniferous forest	A1
<i>Cedripites lusaticus</i> Krutzsch, 1971	Pinaceae, <i>Cedrus</i> type	coniferous forest	A1
<i>Classopollis</i> Pflug, 1953	Cheilepidaceae	coniferous forest	P1
<i>Cunninghamiapollenites janinae</i> Stuchlik & Konzalová, 1991	Taxodiaceae	swamp forest	A1
<i>Cunninghamiapollenites lignitus</i> Nagy, 1969	Taxodiaceae	swamp forest	A1
<i>Cupressacites</i> Bolkhovitina, 1956	Cupressaceae	swamp forest	A1
<i>Cupressacites bockwitzensis</i> Krutzsch, 1971	Cupressaceae, <i>Thuja</i> type	swamp forest	A1
<i>Inaperturopollenites</i> Pflug & Thomson, 1953	Taxodiaceae	swamp forest	A
<i>Inaperturopollenites concedipites</i> (Wodehouse, 1933) Krutzsch, 1971	Taxodiaceae	swamp forest	A1
<i>Inaperturopollenites dubius</i> (Potonié & Venitz, 1934) Thomson & Pflug, 1953	Cupressaceae	swamp forest	A1
<i>Inaperturopollenites hiatus</i> (Potonié, 1931) Thomson & Pflug, 1953	Cupressaceae	swamp forest	A1
<i>Keteleeripollenites</i> Nagy, 1969	Pinaceae, <i>Keteleeria</i> type	coniferous forest	A1
<i>Laricispollenites</i> Nagy, 1985	Pinaceae, <i>Larix</i> type	coniferous forest	A2
<i>Piceapollenites alatus</i> Potonié, 1931	Pinaceae, <i>Pinus haploxylon</i> type	coniferous forest	A
<i>Piceapollis</i> Krutzsch, 1971	Pinaceae, <i>Picea</i> type	coniferous forest	A1
<i>Pinuspollenites</i> Raatz, 1937	Pinaceae, <i>Pinus</i> type	coniferous forest	A

Appendix B continued

Taxon, author	Botanical affinity	Plant communities element	Geofloristic element
<i>Pinuspollenites pactovae</i> (Krutzsch, 1971) Ważyńska-Grabowska, 2002	Pinaceae	coniferous forest	A1
<i>Podocarpidites</i> Cookson, 1947	Podocarpaceae, <i>Podocarpus</i> type	coniferous forest	P1
<i>Psophosphaera pseudotsugoides</i> Krutzsch, 1971	Pinaceae, <i>Larix</i> type, <i>Pinus</i> type	coniferous forest	A
<i>Sciadopityspollenites</i> Raatz, 1937	Taxodiaceae, <i>Sciadopitys</i> type	coniferous forest	A1
<i>Sciadopityspollenites antiquus</i> Krutzsch, 1971	Taxodiaceae, <i>Sciadopitys</i> type	coniferous forest	A1
<i>Sciadopityspollenites crassus</i> Krutzsch, 1971	Taxodiaceae, <i>Sciadopitys</i> type	coniferous forest	A1
<i>Sciadopityspollenites quintus</i> Krutzsch, 1971	Taxodiaceae, <i>Sciadopitys</i> type	coniferous forest	A1
<i>Sciadopityspollenites serratus</i> (Potonié & Venitz, 1934) Thiergart, 1937	Taxodiaceae, <i>Sciadopitys</i> type	coniferous forest	A1
<i>Sequoiapollenites</i> Thiergart, 1937	Taxodiaceae, <i>Sequoia</i> type, <i>Cryptomeria</i> type, <i>Metasequoia</i> type, <i>Sequoiadendron</i> type	coniferous forest	A1
<i>Sequoiapollenites largus</i> (Kremp, 1949) Manum, 1962	Taxodiaceae, <i>Cryptomeria</i> type	swamp forest	A1
<i>Zonalapollenites</i> Pflug, 1953	Pinaceae, <i>Tsuga</i> type	coniferous forest	A1
<i>Zonalapollenites gracilis</i> Krutzsch, 1971	Pinaceae, <i>Tsuga canadensis</i> type	coniferous forest	A1
<i>Zonalapollenites igniculus</i> (Potonié, 1931) Thomson & Pflug, 1953	Pinaceae, <i>Tsuga</i> type,	coniferous forest	A1
<i>Zonalapollenites maximus</i> (Raatz, 1937) Krutzsch, 1971	Pinaceae, <i>Tsuga</i> type	coniferous forest	A1
<i>Zonalapollenites oertlii</i> (Siwak, 1973) Ziemińska-Tworzydło, 2002	Pinaceae, <i>Tsuga blaringhemii</i> type	coniferous forest	A1
<i>Zonalapollenites spectabilis</i> (Doktorowicz-Hrebicka, 1954) Ziemińska-Tworzydło, 1974	Pinaceae, <i>Tsuga diversifolia</i> type	coniferous forest	A1
<i>Zonalapollenites spinosus</i> (Doktorowicz-Hrebicka, 1954) Ziemińska-Tworzydło, 1974	Pinaceae, <i>Tsuga foresti</i> type	coniferous forest	A1
<i>Zonalapollenites verruspinus</i> Krutzsch, 1971	Pinaceae, <i>Tsuga dumosa</i> type, <i>Tsuga chinensis</i> type	coniferous forest	A1
ANGIOSPERMS			
<i>Aceripollenites</i> Nagy, 1969	Aceraceae, <i>Acer</i> type	mesophilous forest	A1
<i>Aceripollenites microrugulatus</i> Thiele-Pfeiffer, 1980	Acearaceae, <i>Acer</i> type	mesophilous forest	A1
cf. <i>Aesculopollis</i> Pocknall & Nichols, 1966	Hippocastanaceae, <i>Aesculus</i> type	mesophilous forest	A1
<i>Aglaoreidia cyclops</i> (Ertman, 1960) Grabowska, 1994	unknown	mesophilous forest	P1
<i>Alangiopollis</i> Krutzsch, 1962	Alangiaceae, <i>Alangium</i> type	mesophilous forest	P
<i>Alnipollenites</i> Potonié, 1931	Betulaceae, <i>Alnus</i> type	riparian forest	A
<i>Alnipollenites verus</i> Potonié, 1931	Betulaceae, <i>Alnus</i> type	riparian forest	A1
<i>Araliaceopollenites</i> Potonié, 1951	Araliaceae	mesophilous forest	P2
<i>Araliaceopollenites edmundi</i> (Potonié, 1931) Potonié, 1951	Araliaceae, <i>Aralia</i> type	mesophilous forest	P2
<i>Araliaceopollenites euphori</i> (Potonié, 1931) Potonié, 1951	Araliaceae	mesophilous forest	P2
<i>Araliaceapollenites reticuloides</i> Thiele-Pfeiffer, 1980	Araliaceae, <i>Hedera</i> type	mesophilous forest	P2
<i>Arecipites</i> Wodehouse, 1933	Arecaceae	mesophilous forest	P2
<i>Arecipites lusaticus</i> Krutzsch, 1970	Arecaceae	mesophilous forest	P2
<i>Arecipites oligocaenicus</i> Krutzsch, 1970	Arecaceae	mesophilous forest	P2
<i>Arecipites pseudoconvexus</i> Krutzsch, 1970	Arecaceae	mesophilous forest	P2
<i>Arecipites wiesaensis</i> Krutzsch, 1970	Arecaceae	mesophilous forest	P2

Appendix B continued

Taxon, author	Botanical affinity	Plant communities element	Geofloristic element
<i>Artemisiaepollenites</i> Nagy, 1969	Asteraceae, <i>Artemisia</i> type	herbaceous plants	A1
<i>Betulaepollenites</i> Potonié, 1934	Betulaceae, <i>Betula</i> type	mesophilous forest	A1
<i>Betulaepollenites betuloides</i> (Pflug, 1953) Nagy, 1969	Betulaceae, <i>Betula</i> type	mesophilous forest	A1
<i>Boehlensipollis hohli</i> Krutzsch, 1962	Elaeagnaceae ?	mesophilous forest	P1
<i>Butomuspollenites</i> (Doktorowicz-Hrebicka, 1957) Ziemińska-Tworzydło, 1994	Butomaceae, <i>Butomus</i> type	aquatic communities	A1
<i>Butomuspollenites longicolpatus</i> (Krutzsch, 1970) Ziemińska-Tworzydło, 1994	Butomaceae, <i>Butomus</i> type	aquatic communities	A2
<i>Caprifoliipites</i> Wodehouse, 1933	Caprifoliaceae	mesophilous forest	A1
<i>Caprifoliipites sambucoides</i> Nagy, 1969	Caprifoliaceae, <i>Sambucus ebulus</i> type	mesophilous forest	A1
<i>Carpinipites</i> Srivastava, 1966	Betulaceae, <i>Carpinus</i> type	mesophilous forest	A
<i>Carpinipites</i> Srivastava, 1966 (= <i>Carpinus orientalis</i>)	Betulaceae, <i>Carpinus orientalis</i> type	mesophilous forest	A1
<i>Carpinipites carpinoides</i> (Pflug, 1953) Nagy, 1985	Betulaceae, <i>Carpinus</i> type	mesophilous forest	A1
<i>Caryapollenites</i> Raatz, 1937	Juglandaceae, <i>Carya</i> type	riparian forest	A1
<i>Caryapollenites simplex</i> (Potonié, 1931) Raatz, 1937	Juglandaceae, <i>Carya</i> type	riparian forest	A1
<i>Caryophyllidites rueterbergensis</i> Krutzsch, 1966	Caryophyllaceae	herbaceous plants	A
<i>Castaneoideaepollis oviformis</i> (Potonié, 1934) Grabowska, 1994	Fagaceae, Castaneoideae, <i>Castanea</i> type, <i>Castanopsis</i> type, <i>Passania</i> type, <i>Lithocarpus</i> type	mesophilous forest	P2
<i>Castaneoideaepollis pusillus</i> (Potonié, 1934) Grabowska, 1994	Fagaceae, Castaneoideae, <i>Castanea</i> type, <i>Castanopsis</i> type, <i>Passania</i> type, <i>Lithocarpus</i> type	mesophilous forest	P2
<i>Celtipollenites</i> Nagy, 1969	Ulmaceae, <i>Celtis</i> type	riparian forest	A1
<i>Celtipollenites verus</i> (Raatz, 1937) Ziemińska-Tworzydło, 1994	Ulmaceae, <i>Celtis</i> type	riparian forest	A1
<i>Cercidiphyllites</i> Mchedlishvili, 1961	Cercidiphyllaceae, <i>Cercidiphyllum</i> type	mesophilous forest	P/A
<i>Cercidiphyllites minimireticulatus</i> (Trevisan 1967) Ziemińska-Tworzydło, 1994	Cercidiphyllaceae, <i>Cercidiphyllum</i> type	mesophilous forest	P/A
<i>Chenopodipollis</i> Krutzsch, 1966	Chenopodiaceae	herbaceous plants	A1
<i>Cichoreacidites gracilis</i> (Nagy, 1969) Nagy, 1985	Asteraceae (=Compositae), Cichorideae	herbaceous plants	A
<i>Cornaceaepollis</i> Stuchlik, 1994	Cornaceae, Cornoideae, Mastixioideae	mesophilous forest	P2
<i>Cornaceaepollis minor</i> (Stuchlik, 1964) Stuchlik, 1994	Cornaceae, Cornoideae	mesophilous forest	P2
<i>Cornaceaepollis satzveyensis</i> (Pflug, 1953) Ziemińska-Tworzydło, 1994	Cornaceae, Mastixioideae	mesophilous forest	P1
<i>Corsinipollenites</i> Nakoman, 1965	Oenotheraceae	herbaceous plants	A1
<i>Corsinipollenites oculusnoctis</i> (Thiergart, 1940) Nakoman, 1965	Oenotheraceae	herbaceous plants	A1
<i>Corsinipollenites oculusnoctis</i> Thiergart, 1940) Nakoman, 1965 <i>parvus</i> Doktorowicz-Hrebicka, 1957	Oenotheraceae	herbaceous plants	A1
<i>Corylopollis coryloides</i> (Pflug, 1953) Ziemińska-Tworzydło, 1994	Betulaceae, <i>Corylus avellana</i> type	mesophilous forest	A2
<i>Cupanieidites eucalyptoides</i> Krutzsch, 1962	Myrtaceae, <i>Eucalyptus</i> type	mesophilous forest	P1
<i>Cyperaceapollis</i> Krutzsch, 1970	Cyperaceae	herbaceous plants	A2
<i>Cyperaceapollis neogenicus</i> Krutzsch 1970	Cyperaceae, <i>Carex</i> type, <i>Caldium</i> type	herbaceous plants	A2
<i>Dicolpopollis kockelii</i> Pflanzl, 1956	Arecaceae, <i>Calamus</i> type	mesophilous forest	P1
<i>Dicolporopollenites middendorfi</i> Potonié, 1931	unknown	mesophilous forest	P1
<i>Diervillapollenites</i> (Doktorowicz-Hrebicka, 1957) Ziemińska-Tworzydło, 1974	Caprifoliaceae	mesophilous forest	A2

Appendix B continued

Taxon, author	Botanical affinity	Plant communities element	Geofloristic element
<i>Diervillapollenites megaspinosus</i> (Doktorowicz-Hrebicka, 1957) Ziemińska-Tworzydło, 1974	Caprifoliaceae, <i>Diervilla</i> type	mesophilous forest	A2
<i>Emmapollis pseudoemmaensis</i> Krutzsch, 1970	unknown	mesophilous forest	P
<i>Engelhardtioipollenites</i> Potonié, 1951	Juglandaceae, <i>Engelhardtia</i> type	mesophilous forest	P2
<i>Engelhardtioipollenites punctatus</i> (Potonié, 1931) Potonié, 1951	Juglandaceae, <i>Engelhardtia</i> type	mesophilous forest	P2
<i>Engelhardtioipollenites quietus</i> (Potonié, 1931) Potonié, 1951	Juglandaceae, <i>Engelhardtia</i> type	mesophilous forest	P1
<i>Eriopites</i> Wodehouse, 1933	Ericaceae	shrub peatbog	A
<i>Eriopites</i> cf. <i>Ledum</i>	Ericaceae, <i>Ledum</i> type	shrub peatbog	A
<i>Eriopites callidus</i> (Potonié, 1931) Krutzsch, 1970	Ericaceae, <i>Calluna</i> type	shrub peatbog	A
<i>Eriopites ericius</i> (Potonié, 1931) Potonié, 1960	Ericaceae, <i>Erica</i> type	shrub peatbog	A
<i>Eriopites roboreus</i> (Potonié, 1931) Krutzsch, 1970	Ericaceae, <i>Rhododendron</i> type, <i>Arbutus unedo</i> type	shrub peatbog	A
<i>Eucommioipollis eucommius</i> (Planderová, 1990) Ziemińska-Tworzydło, 1994	Eucommiaceae, <i>Eucommia</i> type	mesophilous forest	A1
<i>Eucommioipollis parmularius</i> (Potonié, 1934) Ziemińska-Tworzydło, 1994	Eucommiaceae, <i>Eucommia</i> type	mesophilous forest	A1
<i>Faguspollenites</i> Raatz, 1937	Fagaceae, <i>Fagus</i> type	mesophilous forest	A2
<i>Faguspollenites minor</i> Nagy, 1985	Fagaceae, <i>Fagus ferruginea</i> type	mesophilous forest	A2
<i>Fraxinus</i> type 1 Kohlman-Adamska, 1993	Oleaceae, <i>Fraxinus</i> type	riparian forest	A
<i>Fususpollenites fusus</i> (Potonié, 1931) Kedves, 1978	Fagaceae, Quercoidae, <i>Trigonobalanus</i>	mesophilous forest	P1
<i>Graminidites</i> Cookson, 1947	Poaceae (=Gramineae)	herbaceous plants	A
<i>Ilexpollenites iliacus</i> (Potonié, 1931) Thiergart, 1937	Aquifoliaceae, <i>Ilex</i> type	shrub peatbog	P2
<i>Ilexpollenites margaritatus</i> (Potonié, 1931) Raatz, 1937	Aquifoliaceae, <i>Ilex</i> type	shrub peatbog	P2
<i>Ilexpollenites propinquus</i> (Potonié, 1934) Potonié, 1960	Aquifoliaceae, <i>Ilex</i> type	shrub peatbog	P2
<i>Intratropopollenites insculptus</i> Mai, 1961	Tiliaceae, Brownlowioideae, <i>Tilia</i> type	mesophilous forest	A1
<i>Intratropopollenites instructus</i> (Potonié, 1931) Thomson & Pflug, 1953	Tiliaceae, Brownlowioideae, <i>Tilia</i> type	mesophilous forest	A2
<i>Iteapollis angustiporatus</i> (Schneider, 1965) Ziemińska-Tworzydło, 1994	Iteaceae, <i>Itea</i> type	mesophilous forest	P2
<i>Juglandipollis</i> Kohlman-Adamska, 1994	Juglandaceae, <i>Juglans</i> type	mesophilous forest	A1
<i>Juglandipollis juglandoides</i> Kohlman-Adamska, 1994	Juglandaceae, <i>Juglans</i> type	mesophilous forest	A1
<i>Juglandipollis maculosus</i> (Potonié, 1931) Kohlman-Adamska, 1994	Juglandaceae, <i>Juglans</i> type	mesophilous forest	A1
<i>Liquidambarpollenites</i> Raatz, 1937	Altingiaceae, <i>Liquidambar</i> type	riparian forest	A1
<i>Liquidambarpollenites orientalis</i> Nagy, 1969	Altingiaceae, <i>Liquidambar orientalis</i> type	riparian forest	A1
<i>Liquidambarpollenites stigmosus</i> (Potonié, 1931) Raatz, 1937	Altingiaceae, <i>Liquidambar</i> type	riparian forest	A1
<i>Liriodendroipollis verrucatus</i> Krutzsch, 1970	Magnoliaceae, <i>Liriodendron</i> type	mesophilous forest	A1
<i>Lonicerapollis</i> Krutzsch, 1962	Caprifoliaceae, <i>Lonicera</i> type	mesophilous forest	A1
<i>Lonicerapollis gallwiti</i> Krutzsch, 1962	Caprifoliaceae, <i>Lonicera</i> type	mesophilous forest	A1
<i>Lythraeaepollenites bavaricus</i> Thiele-Pfeiffer, 1980	Lythraceae, <i>Lawsonia</i> type, <i>Rotala</i> type, <i>Ammannia</i> type	riparian forest	A
<i>Magnolipollis</i> Krutzsch, 1970	Magnoliaceae, <i>Magnolia</i> type	mesophilous forest	P1
<i>Mediocolpopollis</i> Krutzsch, 1959	unknown	mesophilous forest	P

Appendix B continued

Taxon, author	Botanical affinity	Plant communities element	Geofloristic element
<i>Mediocolpopollis compactus</i> Krutzsch, 1959	unknown	mesophilous forest	P
<i>Milfordia incerta</i> (Pflug & Thomson, 1953) Krutzsch, 1961	Restionaceae, Centrolepidaceae	mesophilous forest	P1
<i>Milfordia hungarica</i> (Kedves, 1965) Krutzsch & Vanhoorne, 1970	Restionaceae, Centrolepidaceae, Flagellariaceae	mesophilous forest	P1
<i>Miocaenipollis miocaenicus</i> Krutzsch, 1966	unknown	mesophilous forest	P/A
<i>Monocolpopollenites</i> Pflug & Thomson, 1953	Arecaceae	mesophilous forest	P
<i>Monocolpopollenites</i> cf. <i>Ginkgo</i>	Ginkgopsida, <i>Ginkgo</i> type	mesophilous forest	P1
<i>Myricipites</i> Wodehouse, 1933	Myricaceae	shrub peatbog	P2
<i>Myricipites bituitus</i> (Potonié, 1931) Nagy, 1969	Myricaceae, <i>Myrica gale</i> type	shrub peatbog	P2
<i>Myricipites coryphaeus</i> (Potonié, 1931) Potonié, 1960	Myricaceae	shrub peatbog	P2
<i>Myricipites microcoryphaeus</i> (Potonié, 1931) Słodkowska, 1994	Myricaceae	shrub peatbog	P2
<i>Myricipites myricoides</i> (Kremp, 1949) Nagy, 1969	Myricaceae, <i>Myrica</i> type	shrub peatbog	P2
<i>Myricipites rurensis</i> (Pflug & Thomson, 1953) Nagy, 1969	<i>Myrica</i> type	shrub peatbog	P2
<i>Myriophyllumpollenites</i> Nagy, 1969	Halorrhagaceae	aquatic communities	A2
<i>Myrtacidites</i> Cookson & Pike, 1954	Myrtaceae	mesophilous forest	P
<i>Nupharipollis echinatus</i> Krutzsch, 1970	Nymphaeaceae, <i>Nuphar</i> type	aquatic communities	A
<i>Nupharipollenites kedvesii</i> Nagy, 1969	Nymphaeaceae, <i>Nuphar</i> type	aquatic communities	A
<i>Nymphaepollenites neogenicus</i> Thiele-Pfeiffer, 1980	Nymphaeaceae, <i>Nymphaea</i> type	aquatic communities	A2
<i>Nyssapollenites</i> Thiergart, 1937	Nyssaceae, <i>Nyssa</i> type	mesophilous forest	A1
<i>Nyssapollenites analepticus</i> (Potonié, 1934) Planderová, 1990	Nyssaceae, <i>Nyssa</i> type	swamp forest	A1
<i>Nyssapollenites contortus</i> (Pflug & Thomson, 1953) Nagy, 1985	Nyssaceae, <i>Nyssa</i> type	swamp forest	A1
<i>Nyssapollenites pseudocruciatus</i> (Potonié, 1931) Thiergart, 1937	Nyssaceae, <i>Nyssa</i> type	swamp forest	A1
<i>Nyssapollenites rodderensis</i> (Thiergart, 1947) Kedves, 1978	Nyssaceae, <i>Nyssa</i> type	swamp forest	A1
<i>Oleoidearumpollenites microreticulatus</i> (Pflug & Thomson, 1953) Ziemińska-Tworzydło, 1994	Oleaceae	mesophilous forest	A1
<i>Oligopollis</i> Krutzsch, 1959	unknown	mesophilous forest	P/A
<i>Oligopollis pentaporis</i> Krutzsch, 1959	unknown	mesophilous forest	P/A
<i>Ostryoipollenites rhenanus</i> (Thomson, 1950) Potonié, 1951	Betulaceae, <i>Ostrya</i> type	mesophilous forest	A1
<i>Polyvestibulopollenites juglandaceoides</i> Krutzsch & Vanhoorne, 1977	Juglandaceae	mesophilous forest	P1
<i>Pescarioipollis</i> Krutzsch, 1962	Polygonaceae, <i>Polygonum</i> type	herbaceous plants	A
<i>Plantaginacearumpollenites</i> Nagy, 1963	Plantaginaceae	herbaceous plants	A
<i>Platanipollis ipelensis</i> (Pačtová, 1966) Grabowska, 1994	Platanaceae, <i>Platanus</i> type	mesophilous forest	P1
<i>Platycaryapollenites</i> Nagy, 1969	Juglandaceae, <i>Platycarya</i> type	mesophilous forest	P2
<i>Platycaryapollenites miocaenicus</i> Nagy, 1969	Juglandaceae, <i>Platycarya</i> type	mesophilous forest	P2
<i>Platycaryapollis levis</i> (Potonié, 1931) Krutzsch & Vanhoorne, 1977	Juglandaceae, <i>Platycarya</i> type	mesophilous forest	P2
<i>Potamogetonacidites</i> Sah, 1967	Potamogetonaceae, <i>Potamogeton</i> type	aquatic communities	A
<i>Pseudotyphoipollis</i> Krutzsch, 1970	Apocynaceae, Gentianaceae	mesophilous forest	P2
<i>Pseudotyphoipollis punctiporatus</i> Krutzsch, 1970	Apocynaceae <i>Apocynum</i> type, Gentianaceae	mesophilous forest	P2
<i>Pterocaryapollenites</i> Thiergart, 1937	Juglandaceae, <i>Pterocarya</i> type	riparian forest	A1

Appendix B continued

Taxon, author	Botanical affinity	Plant communities element	Geofloristic element
<i>Punctiatoripollis</i> Krutzsch, 1966	Alismataceae, <i>Sagittaria</i> type	herbaceous plants	A
<i>Quercoidites</i> Potonié, Thomson & Thiergart, 1950	Fagaceae, Quercoideae, <i>Quercus</i> type	mesophilous forest	P/A
<i>Quercoidites asper</i> (Pflug & Thomson) Słodkowska, 1994	<i>Quercus robur</i> type	mesophilous forest	A1
<i>Quercoidites henrici</i> (Potonié, 1931) Potonié, Thomson & Thiergart, 1950	Quercoideae	mesophilous forest	P2
<i>Quercoidites microhenrici</i> (Potonié, 1931) Potonié, Thomson & Thiergart, 1950	Quercoideae	mesophilous forest	P2
<i>Quercopollenites robur</i> type Nagy, 1969	<i>Quercus robur</i> type	mesophilous forest	A1
<i>Reductipollis</i> Krutzsch, 1966	Buxaceae ?	mesophilous forest	P
<i>Rhuspollenites</i> Thiele-Pfeiffer, 1980	Anacardiaceae, <i>Rhus</i> type	mesophilous forest	A1
<i>Rhuspollenites ornatus</i> Thiele-Pfeiffer, 1980	<i>Rhus</i> type	mesophilous forest	A1
<i>Reevesiapollis triangulus</i> (Mamczar, 1960) Krutzsch, 1970	Sterculiaceae, <i>Reevesia</i> type	mesophilous forest	P2
<i>Salixipollenites</i> Srivastava, 1966	Salicaceae, <i>Salix</i> type	riparian forest	A2
<i>Sapotaceoidaepollenites</i> Potonié, Thomson & Thiergart, 1950	Sapotaceae	mesophilous forest	P1
<i>Sapotaceoidaepollenites manifestus</i> (Potonié, 1931) Potonié, 1960	Sapotaceae	mesophilous forest	P1
<i>Sapotaceoidaepollenites oblongus</i> (Pflug & Thomson, 1953) Grabowska, 1994	Sapotaceae	mesophilous forest	P1
<i>Sapotaceoidaepollenites sapotoides</i> (Pflug & Thomson, 1953) Potonié, 1960	Sapotaceae	mesophilous forest	P1
cf. <i>Slowakipollis</i> Krutzsch, 1962	Elaeagnaceae	swamp forest	A
<i>Slowakipollis elaeagnoides</i> Krutzsch, 1962	Elaeagnaceae, <i>Elaeagnus</i> type	swamp forest	A
<i>Sparganiaceapollenites</i> Thiergart, 1937	Sparganiaceae	aquatic communities	A
<i>Sparganiaceapollenites magnoides</i> Krutzsch, 1970	Sparganiaceae	aquatic communities	A
<i>Sparganiaceapollenites neogenicus</i> Krutzsch, 1970	Sparganiaceae, <i>Sparganium</i> type	aquatic communities	A
<i>Sparganiaceapollenites polygonalis</i> Thiergart, 1937	Sparganiaceae	aquatic communities	A
<i>Sparganiaceapollenites sparganioides</i> (Meyer, 1956) Krutzsch, 1970	Sparganiaceae, <i>Sparganium</i> type	aquatic communities	A
<i>Spinulaepollis arceuthobioides</i> Krutzsch, 1962	Loranthaceae, <i>Arceuthobium</i> type	mesophilous forest	A1
<i>Subtriporopollenites anulatus</i> Pflug & Thomson, 1953	Juglandaceae, <i>Carya</i> type	mesophilous forest	P1
<i>Symplocoipollenites</i> Potonié, 1951	Symplocaceae	mesophilous forest	P2
<i>Symplocoipollenites latiporis</i> (Pflug & Thomson, 1953) Słodkowska, 1994	Symplocaceae, <i>Symplocos</i> type	mesophilous forest	P2
<i>Symplocoipollenites orbis</i> (Pflug & Thomson, 1953) Krutzsch, 1971	Symplocaceae, <i>Symplocos</i> type	mesophilous forest	P1
<i>Symplocoipollenites rarobaculatus</i> (Thiele-Pfeiffer, 1980) Ashraf & Mosbrugger, 1996	Symplocaceae, <i>Symplocos</i> type	mesophilous forest	P2
<i>Symplocoipollenites rotundus</i> Potonié, 1931 ex Potonié, 1960	Symplocaceae	mesophilous forest	P2
<i>Symplocoipollenites vestibulum</i> (Potonié, 1931) Potonié, 1960	Symplocaceae, <i>Symplocos</i> type	mesophilous forest	P2
<i>Tetracolporopollenites</i> Pflug & Thomson, 1953	heterogenous genus	mesophilous forest	P
<i>Trapapollis</i> Kohlman-Adamska, 1994	Trapaceae, <i>Trapa</i> type	aquatic communities	A1
<i>Triatriopollenites engelhardtoides</i> Roche, 1973	Juglandaceae, <i>Engelhardtia</i> type	mesophilous forest	P1
<i>Tricolpopollenites</i> Pflug & Thomson, 1953	heterogenous genus	mesophilous forest	P/A
<i>Tricolpopollenites sinuosimuratus</i> Trevisan, 1967	Oleaceae, <i>Fraxinus</i> type	riparian forest	A
<i>Tricolporopollenites</i> Pflug & Thomson, 1953	heterogenous genus	mesophilous forest	P/A

Appendix B continued

Taxon, author	Botanical affinity	Plant communities element	Geofloristic element
<i>Tricolporopollenites bruehlensis</i> (Thomson, 1950) Grabowska, 1994	Clethraceae, Cyrillaceae, Rosaceae	shrub peatbog	P2
<i>Tricolporopollenites</i> type <i>Corylopsis</i>	Hamamelidaceae, <i>Corylopsis</i> type	mesophilous forest	A1
<i>Tricolporopollenites dolium</i> (Potonié, 1931) Thomson & Pflug, 1953	unknown	mesophilous forest	P2
<i>Tricolporopollenites eofagoides</i> Krutzsch & Vanhoorne, 1977	Fagoidae	mesophilous forest	P1
<i>Tricolporopollenites</i> cf. <i>eomaximus</i> Krutzsch & Vanhoorne, 1977	unknown	mesophilous forest	P1
<i>Tricolporopollenites europaeus</i> Krutzsch & Vanhoorne, 1977	unknown	mesophilous forest	P
<i>Tricolporopollenites exactus</i> (Potonié, 1931) Grabowska, 1994	Clethraceae, <i>Clethra</i> type, Cyrillaceae	shrub peatbog	P2
<i>Tricolporopollenites</i> cf. <i>exactus</i> (Potonié, 1931) Grabowska, 1994	Clethraceae, <i>Clethra</i> type, Cyrillaceae	shrub peatbog	P2
<i>Tricolporopollenites</i> type Fabaceae	Fabaceae (=Leguminosae)	mesophilous forest	A1
<i>Tricolporopollenites fallax</i> (Potonié, 1934) Krutzsch, 1960	Fabaceae, Fagaceae, Combretaceae, Verbenaceae	mesophilous forest	P2
<i>Tricolporopollenites kruschi accessorius</i> (Potonié, 1934) Thomson & Pflug, 1953	Nyssaceae, <i>Nyssa</i> type	swamp forest	A1
<i>Tricolporopollenites liblarensis</i> (Thomson, 1950) Grabowska, 1994	Fabaceae, Fagaceae, Combretaceae, Verbenaceae	mesophilous forest	P2
<i>Tricolporopollenites</i> type <i>Ligustrum</i> , <i>Syringa</i>	Oleaceae, <i>Ligustrum</i> type, <i>Syringa</i> type	mesophilous forest	A1
<i>Tricolporopollenites mansfeldensis</i> Krutzsch, 1969	Rhizophoraceae, <i>Rhizophora</i> type	mesophilous forest	P1
<i>Tricolporopollenites marcodurensis</i> Pflug & Thomson, 1953	Vitaceae, <i>Parthenocissus</i> type	mesophilous forest	P1
<i>Tricolporopollenites megaexactus</i> (Potonié, 1931) Thomson & Pflug, 1953	Clethraceae, Cyrillaceae	shrub peatbog	P2
<i>Tricolporopollenites oleoides</i> Krutzsch & Vanhoorne, 1977	Plumbaginaceae, <i>Armeria</i> type	mesophilous forest	P
<i>Tricolporopollenites</i> type <i>Parrotia</i>	Hamamelidaceae, <i>Parrotia</i> type	mesophilous forest	A1
<i>Tricolporopollenites</i> type Polygalaceae	Polygalaceae	herbaceous plants	A2
<i>Tricolporopollenites</i> type <i>Polygonum</i>	Polygonaceae, <i>Polygonum</i> type	herbaceous plants	A2
<i>Tricolporopollenites pseudocingulum</i> (Potonié, 1931) Thomson & Pflug, 1953	Fagaceae, Fagoidae	mesophilous forest	P2
<i>Tricolporopollenites</i> cf. <i>pseudocingulum</i> (Potonié, 1931) Thomson & Pflug, 1953	Fagaceae, Fagoidae	mesophilous forest	P2
<i>Tricolporopollenites</i> cf. <i>pusillus</i> (Potonié, 1934) Thomson & Pflug, 1953	Fagaceae, Castaneoideae, <i>Castanea</i> type, <i>Castanopsis</i> type, <i>Passania</i> type, <i>Lithocarpus</i> type	mesophilous forest	P2
<i>Tricolporopollenites retiformis</i> (Pflug & Thomson, 1953) Krutzsch, 1961	heterogenous genus, p.p. Salicaceae	riparian forest	A1
<i>Tricolporopollenites</i> type <i>Reseda</i>	Resedaceae, <i>Reseda</i> type	herbaceous plants	A1
<i>Tricolporopollenites</i> type Rosaceae	Rosaceae	shrub peatbog	A1
<i>Tricolporopollenites staretsloensis</i> Krutzsch & Pacltová, 1969	Hamamelidaceae, <i>Parrotia</i> type, <i>Distylium</i> type	mesophilous forest	P2
<i>Tricolporopollenites</i> type <i>Vitis</i>	Vitaceae, <i>Vitis</i> type	mesophilous forest	A1
<i>Tripoporopollenites</i> Pflug & Thomson, 1953	heterogenous genus	mesophilous forest	P/A
<i>Tripoporopollenites megagranifer</i> (Potonié, 1931) Thomson & Pflug, 1953	Betulaceae ?	mesophilous forest	P2
<i>Tripoporopollenites palaeobetuloides</i> Krutzsch & Vanhoorne, 1977	Betulaceae ?	mesophilous forest	P1
<i>Tripoporopollenites robustus</i> Pflug, 1953	Betulaceae ?	mesophilous forest	P2
<i>Tubulifloridites</i> (Cookson, 1947) Potonié, 1960	Asteraceae (=Compositae), Asteroideae	herbaceous plants	A
<i>Ulmipollenites</i> Wolff, 1934	Ulmaceae, <i>Ulmus</i> type	riparian forest	A2
<i>Ulmipollenites undulosus</i> Wolff, 1934	<i>Ulmus laevis</i> type	riparian forest	A2

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Taxon, author	Botanical affinity	Plant communities element	Geofloristic element
<i>Umbelliferoipollenites</i> Venkatachala & Kar, 1968	Apiaceae (=Umbelliferae)	herbaceous plants	A2
<i>Verrutricolporites theacoides</i> Roche & Schuler, 1976	Theaceae	mesophilous forest	P2
<i>Vitispollenites</i> Thiele-Pfeiffer, 1980	Vitaceae, <i>Vitis</i> type	mesophilous forest	A1
<i>Zelkovaepollenites</i> Nagy, 1969	Ulmaceae, <i>Zelkova</i> type	mesophilous forest	A1
NORMAPOLLES Group (Pflug, 1953) Góczán, Krutzsch & Pacltová, 1967	unknown, heterogenous, extinct group, partly related to: Betulaceae, Casuarinaceae, Hamamelidae, Juglandales, Myricales, Rhoipteleaceae, Urticales		
<i>Basopollis</i> Pflug, 1953		mesophilous forest	P1
<i>Extratropipollenites parmatum</i> (Pflug, 1953) Skarby, 1968		mesophilous forest	P1
<i>Interpollis</i> Krutzsch, 1961		mesophilous forest	P1
<i>Longanulipollis</i> cf. <i>capsula</i> (Pflug, 1953) Krutzsch & Góczán, 1967		mesophilous forest	P1
<i>Nudopollis</i> Pflug, 1953		mesophilous forest	P1
<i>Nudopollis endangulatus</i> (Pflug, 1953) Pflug, 1953		mesophilous forest	P1
<i>Nudopollis minutus</i> Zaklinskaya, 1963		mesophilous forest	P1
<i>Nudopollis thiergartii</i> (Thomson & Pflug, 1953) Pflug, 1953		mesophilous forest	P1
<i>Oculopollis concentus</i> Pflug, 1953		mesophilous forest	P1
<i>Semioculopollis</i> sp. A. Tschudy, 1975		mesophilous forest	P1
<i>Stephanoporopollenites hexaradiatus</i> (Thiergart, 1940) Thomson & Pflug, 1953		mesophilous forest	P1
<i>Trudopollis</i> (Pflug, 1953) Krutzsch, 1967		mesophilous forest	P1
<i>Trudopollis</i> cf. <i>bulboformis</i> Zaklinskaya, 1963		mesophilous forest	P1
<i>Vacuopollis semiconcavus</i> Pflug, 1953		mesophilous forest	P1

Geofloristic element:

P — generally Palaeotropical element, P1 — tropical element, P2 — subtropical element, A — generally Arctotertiary element, A1 — warm temperate element, A2 — cool temperate element