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Reconstruction of the sedimentary environment of phytogenic deposits in the Tomisławice opencast mine (Konin Region, central Poland)

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Palynological analysis of the Tomisławice opencast mine deposits has allowed reconstruction of the plant communities and investigation of the evolution of sedimentary environments at various stages of lignite-forming marsh development, recorded in the composition of pollen assemblages from deposits of the 1st Mid-Polish lignite seam (MPLS-1). Rich pollen communities from an ~9 m thick section has enabled study of the succession of plant communities and of the evolution of phytogenic sedimentation. The pollen succession indicates that the assemblages in the whole lignite seam represent the VIII *Celtipollenites verus* pollen Zone. Slight differences in the composition of the communities reflect different stages of basin development, depending more on the variable water dynamics than on climatic oscillations. Lignite of the MPLS-1 developed in a continental regime on alluvial plains. Changes in the succession of plant communities in the Tomisławice section record flooding-drainage cycles caused by groundwater level oscillations. Peat bog accumulation took place in river basins, in which the lack of siliciclastic intercalations within the massive lignite seams points to weak fluvial dynamics. A rise in groundwater level and/or surface water resulted in flooding of the marshes and the formation of an extensive shallow lake basin, as shown by the presence of freshwater algae and pollen of aquatic plants. The section as a whole does not record an increased contribution of thermophilic plant taxa. The flora was generally dominated by warm-temperate and thermophilic species, without the participation of strongly thermophilic vegetation, which indicates that the lignite seam in the Tomisławice opencast mine was formed in the generally stable conditions of a warm temperate climate.

Key words: palynology, lignite seam, plant communities, palaeobotanical reconstruction, Neogene, central Poland.

INTRODUCTION

The palynological studies of the 1st Mid-Polish lignite seam (MPLS-1) in the Tomisławice opencast mine described herein are a continuation of multifaceted research conducted in recent years within the Konin lignite-forming sedimentary basin (Widera, 2016, 2020; Widera et al., 2017a, 2021a, b; Chomiak, 2020a; Słodkowska and Widera, 2021, Worobiec et al., 2021, 2022). Tomisławice is one of many opencast mines in the Konin lignite basin (central Poland; Fig. 1). The exploited MPLS-1 accumulated in the later part of the Middle Miocene. It represents the last significant seam in the Miocene lignite-forming cycle and constitutes a clear, extensive correlation level in the Polish Lowlands (Worobiec et al., 2021, 2022; Słodkowska and Widera, 2021). In the vicinity of Konin town, the seam is fully developed with a thickness of up to 20 m. According to palynological data, during the formation of the MPLS-1 deposits, the climate was warm-temperate, with high humidity, favorable for the development of extensive marshes, as shown by the wide lateral extent of ths seam. The seam is dominated by lithotypes of lignite which indicate various sub-environments representing different types of marsh (Widera, 2016; Widera et al., 2021a). Detailed data on the research conducted on MPLS-1 in the Polish Lowlands was published by Słodkowska and Widera (2021).

The generally stable conditions of phytogenic sedimentation were disturbed by brief episodes when siliciclastic material was fed to the basin. Between the compact lignite seams there are sandy laminae and thin beds up to 2 cm thick separating different petrographic types of lignite. Episodes of sandy sedimentation were related to basin dynamics and to rapid subsidence of the sedimentary surface (Kasiński and Słodkowska, 2016), and above all to external factors such as frequent floods (Widera, 2016, 2020; Widera et al., 2017a; Chomiak, 2020a; Chomiak et al., 2020). Increased influx of terrigenous material is related to changes in the fluvial environment, as water level oscillations recorded in the facies succession from swamps to lakes (Chomiak et al., 2020; Widera et al., 2021a).

Due to the economic importance of the Konin lignite deposits, geological studies of the area began in the 20th century (Ciuk, 1980; Piasecki, 1999). Palynological studies of the lignite had been earlier made (Kremp, 1949; Mamczar, 1960a, b; Ciuk and Grabowska, 1991; Sadowska and Giża, 1991). In recent years, there have been several geological and palynological studies of the lignites in the Konin Basin (Słodkowska and Paruch-Kulczycka, 2008; Kasiński et al., 2010; Widera, 2007,

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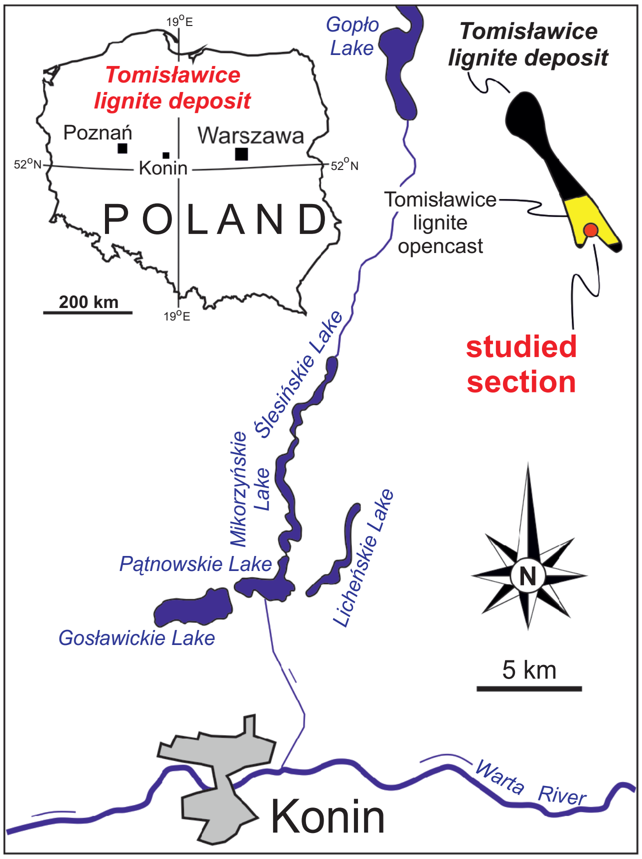

Fig. 1. Location map of the studied section of the first Mid-Polish lignite seam (MPLS-1) with regard to the Tomisławice opencast lignite mine in central Poland

2020; Widera et al., 2021a, b; Słodkowska and Widera, 2021; Worobiec et al., 2021, 2022). The present paper contributes to a more detailed understanding of the geological structure, of the development of plant palaeocommunities, and of facies changes associated with the lignite-forming processes. It also focuses on how climate changes had significant impact on these processes.

GEOLOGICAL SETTING

The Tomisławice lignite opencast mine is located ~25–30 km to the north-east of the town of Konin in central Poland, and the section investigated in detail has the following geographic coordinates: 52°27'29.9''N and 18°31'11.1''E (Fig. 1). In the study area, the sub-Cenozoic bedrock is composed of Upper Cretaceous marls (Dadlez et al., 2000). The only Paleogene strata are of early Oligocene age, consisting mainly of marine glauconitic sands (Widera, 2021). The Neogene encompasses two main lithostratigraphic units. The lower Koźmin Formation, deposited from the early to the middle Miocene, is predominantly built of sands with coaly intercalations. The upper Poznań Formation, which is middle Miocene to early Pliocene in age, is subdivided into two lithostratigraphic units: the Grey Clays and the Wielkopolska Member (Maciaszek et al., 2020; Fig. 2).

The lignite seam examined in this study belongs to the first Mid-Polish group and is referred to as the first Mid-Polish lignite seam – MPLS-1 (Piwocki and Ziembińska-Tworzydło, 1997; Kasiński and Słodkowska, 2016; Widera, 2021) or the Konin seam (Sadowska and Giża, 1991). The MPLS-1 is 6.9 m thick on average (3–12 m) and spans almost the entire Grey Clays Member in the Tomisławice opencast mine (Widera, 2021). The accumulation of this lignite seam started during the last peak of the Miocene Climatic Optimum (MCO) and continued as the climate started to cool (Kasiński and Słodkowska, 2016; Bechtel et al., 2019, 2020; Worobiec et al., 2021, 2022; Słodkowska and Widera, 2021), i.e., at ~15–14.3 Ma (Widera et al., 2021a, b).

The section studied (9.2 m thick) of the MPLS-1, with the sampling points shown, includes three macroscopic clastic interbeds (Fig. 2). These sandy-silty layers are interpreted as being typical of crevasse splays (Widera, 2016, 2020; Widera et al., 2017a; Chomiak, 2020a), while the clayey beds correspond to deposition in a lake that existed in the mire area, i.e., in the overbank zone of the fluvial plain of a mid-Miocene fluvial system (Chomiak et al., 2020; Widera et al., 2021b). The MPLS-1 at Tomisławice mine is characterized by an average ash yield at <20 wt.% and a low average sulphur content at <1.2 wt.% (Bechtel et al., 2019, 2020). The siliciclastic interbeds may double the ash content in some parts of the MPLS-1 (Chomiak, 2020b). Based on the reflectance coefficient (Ro <0.3%) and carbon content ($60<C^{daf}<70\%$), the lignite studied should be classified as humic and low-rank B or ortho-lignite (Kwiecińska and Wagner, 2001).

On top of the MPLS-1 (≈ the top of the Grey Clays Member) rests the Wielkopolska Member, which is late middle Miocene to early Pliocene in age. It is predominantly composed of overbank muds with palaeosoil horizons (>95 vol.%), as well as channel-fill sands and muds (<5 vol.%). These fine-grained deposits represent a late Neogene fluvial system, i.e., anastomosing (e.g., Widera et al., 2017b, 2019) or transitional anastomosing-to-meandering (Zieliński and Widera, 2020; Kędzior et al., 2021). The Neogene succession is capped by glaciogenic Quaternary deposits such as glacial tills, gravels, sands and muds.

MATERIAL AND METHODS

Thirty-five samples from the wall of the Tomisławice opencast mine were analysed palynologically. Samples were collected from a 9 m section in the wall of the open pit at ~25 cm intervals. Various lignite lithotypes characterized by different structures and textures occur in the section analysed (Fig. 2). Massive detritic lignite (DLm, samples 1–4) is present in the basal part of the wall, followed by massive, fractured xylodetritic lignite [XDLm (fr), samples 5–14], detroxylitic lignite (XDLm, samples 15–18), massive xyldetritic lignite (XDLm, samples 19–23), massive detritic lignite (DLm, samples 24–29) and, in the uppermost part, horizontally laminated xylodetritic lignite (XDLh, samples 30–35). Samples for palynological research were taken from all lignite lithotypes. Between the lignite layers at 56.6 and 58.0 m a.s.l. there were two 2 cm thick beds of very fine sands, which were not sampled for palynological analysis.

The lignite samples analysed were processed in the laboratory using standard palynological maceration methods (Fegri and Iversen, 1978). HCl was used to eliminate carbonates, then KOH was applied to remove humic compounds. The organic and mineral fractions were separated by density separation using $ZnCl_2$ with a density of 2.21 g/cm^3. Finally, cellulose was removed by acetolysis according to Erdtman (1954). From the macerates obtained using this procedure, microscope preparations with dimensions of 20 x 20 mm were made, and analysed under the ARISTOPLAN biological microscope at 400x and 640x magnifications. The entire palynological matter – palyno-

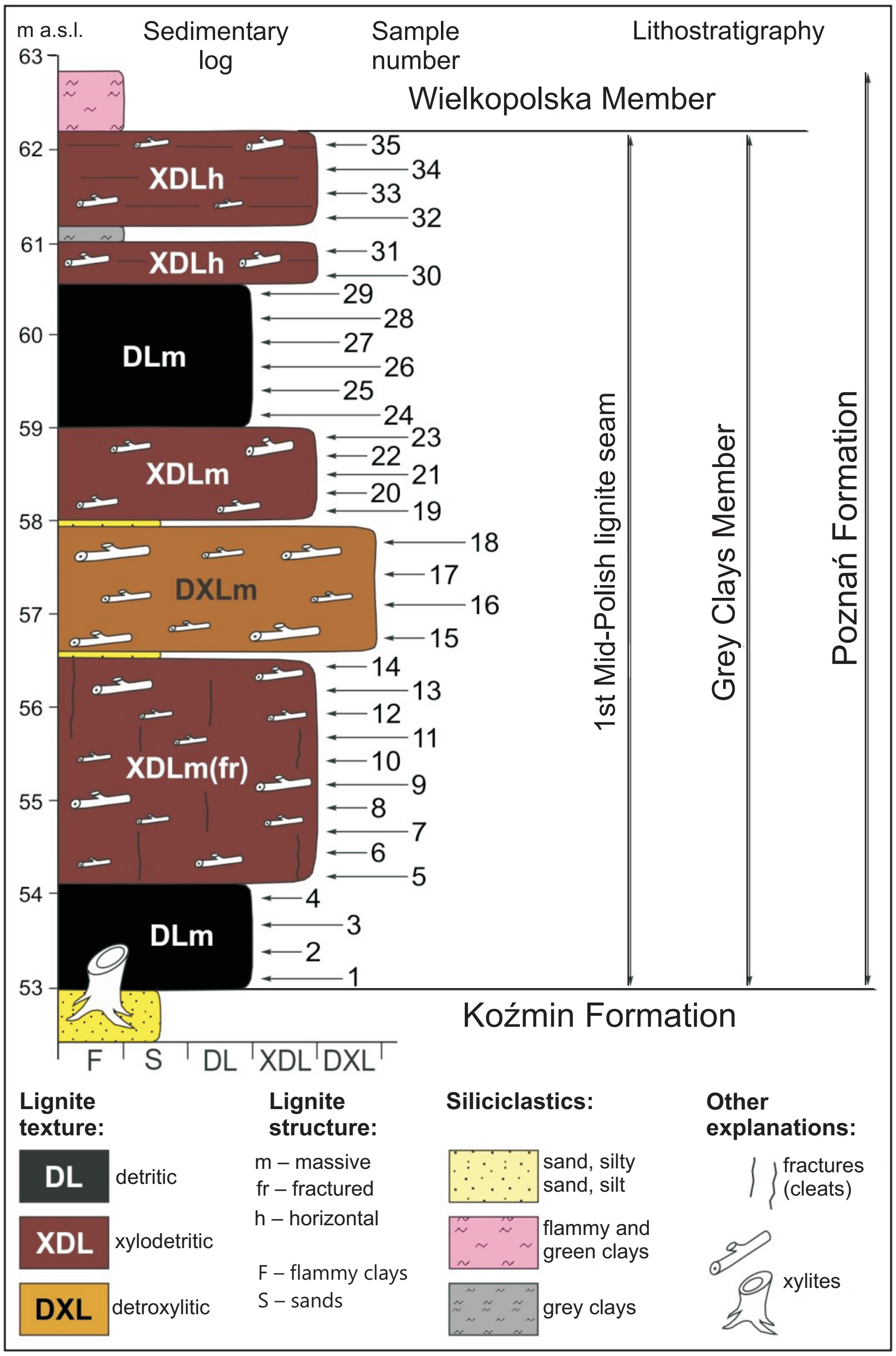

Fig. 2. Detailed sketch-map of the studied section showing the macropetrography, stratigraphy and location of samples in the first Mid-Polish (first Lusatian) lignite seam (MPLS-1) examined at the Tomisławice opencast mine lignite in central Poland

For the location of the studied section, see Figure 1

morphs (sporomorphs) and phytoclasts (fragments of wood, cuticule) – was analysed in the microscopic slides. The abundance and preservation of sporomorphs within the section were satisfactory with only a few samples showing slight depletion of the assemblage. Pollen spores and grains were determined using morphological systematics related, wherever possible, to the botanical affinity of the taxa (Stuchlik et al., 2001, 2002, 2009, 2014). A total of 122 spore and pollen grains and phytoplankton taxa, with 14 taxa of spores, 13 taxa of gymnosperms, 89 taxa of angiosperms and 6 taxa of phytoplankton were determined (Appendix 1). The presence of phytoclasts was also recorded. The contribution content of the more important sporomorphs is shown in the pollen diagram (Fig. 3). The Neogene pollen-spore zones were correlated with the palynological scheme for Poland (Piwocki and Ziembińska-Tworzydło, 1997). The fossil pollen taxa distinguished in the Tomisławice open-

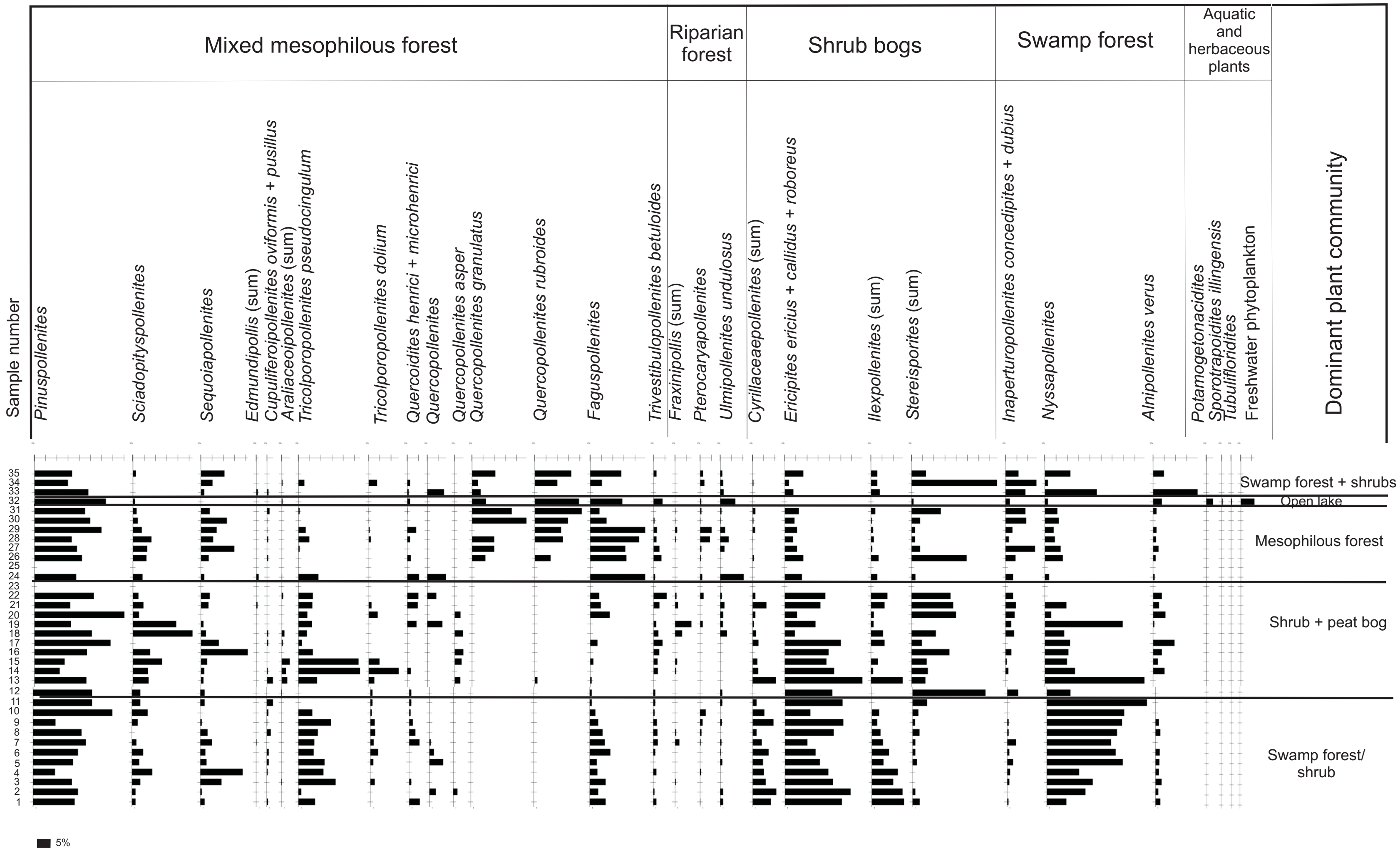

Fig. 3. Simplified percentage pollen diagram of the first Mid-Polish lignite seam (MPLS-1) in the Tomisławice opencast lignite mine

-cast lignite mine were compared to their respective contemporary, botanical taxa (Appendix 2). The following palaeofloral elements were distinguished: palaeotropical (P), including tropical (P1) and subtropical (P2); "arctotertiary" (A), including warm temperate (A1) and temperate (A2); as well as cosmopolitan (P/A) taxa (Planderova et al., 1993; Ziembińska-Tworzydło et al., 1994; Stuchlik et al., 2001, 2002, 2009, 2014).

RESULTS

Samples analysed in the >9 m thick lignite section in the Tomisławice opencast mine represent the same palynostratigraphic interval characteristic of the first mid-Polish lignite seam (MPLS-1), correlated with the VIII *Celtipollenites verus* Zone (middle Miocene-Langhian; Piwocki and Ziembińska-Tworzydło, 1997; Słodkowska, 1998; Ziembińska-Tworzydło, 1998). Rich pollen communities allow to follow the succession of plant communities and the development of phytogenic sedimentation in detail (Appendices 1 and 2).

Differences in the composition and percentage of pollen taxa in the samples indicate different stages in the development of the sedimentary basin, related mainly to slight changes in the groundwater table. Water dynamics had a smaller impact because major breaks caused by increased flow and influx of mineral material were not observed in the phytogenic succession. As indicated by analysis of the pollen diagram (Fig. 3), the composition of the pollen assemblages was less influenced by changes in the ambient temperature than by changes in humidity. The pollen came from peat-forming habitats and from forests covering the area outside the mire. Communities of water plants, moss and rush vegetation, swamp forest and, to a lesser extent, shrub bog, are important for peat formation. They generally represent azonal vegetation, reacting weakly to thermal changes. Due to the similar sedimentary conditions of the peat deposits, the peat-forming communities recorded in the entire section had a similar floral composition due to the similar sedimentary conditions. In the mixed mesophilous forests growing on the margins of the sedimentary basin, the content of thermophilic elements indicating climate change was constant in the section analysed, thus indicating a stable climate.

In the entire Tomisławice section (Fig. 3), spores of bryophytes and ferns were dominated by a large contribution (reaching up to 30% in some samples) of spores of peat mosses (Sphagnaceae), with the extinct species *Distancoraesporis ancoris, D. germanicus, Stereisporites (Distancoraesporis) reutherbergensis, Stereisporites* sp.*, S. cyclus, S. involutus, S. macroides, S. minor, S. stereoides* and *S. validus*. There were only few species of ferns from the Polypodiaceae and Osmundaceae families. Pollen grains of gymnosperms were represented by the pollen of upland forest trees: *Pinuspollenites* up to 28.4%, *Sciadopityspollenites* up to 21.3%, and *Sequoiapollenites* up to 12.1%. Among coniferous trees, pollen of trees from swamp forests, i.e. *Inaperturopollenites dubius*, reached 8.5% and *I. concedipites* had a lower contribution of up to 2.7%. The pollen assemblage of angiosperms was characterized by high frequency and taxonomic diversity, with abundant pollen of: *Nyssapollenites* up to 35.6%, *Tricolporopollenites pseudocingulum* up to 22.1%, *Ericipites* in total up to 20.9%, *Quercopollenites granulatus* up to 19.5%, *Q. rubroides* up to 16.8%, *Ilex* in total up to 7.6%. Pollen of the thermophilous fossil species occurred regularly, but in small amounts, not exceeding 1.5%: *Araliaceoipollenites* (4 species) and *Cornaceaepollenites satzveyensis, Cupuliferoipollenites pusillus, C. oviformis, Cyrillaceaepollenites brühliosis, Edmundipollis edmundi, Platycaryapollenites* sp.*, Quercoidites henrici, Quercoidites microhenrici, Reevesiapollis triangulus, Tricolporopollenites dolium, T. fallax, T. liblarensis, T. mangiferoides, T. staresedloensis* and *T. theacoides*. Thermophilous taxa did not reach larger concentrations in any sample from the exposure. The maximum values were achieved by *T. dolium*, at 10.8% in one sample. The share of pollen of thermophilous plants from the mixed mesophilous forest did not change in the subsequent intervals of the section. In the Tomisławice section, no signal indicating greater climate changes was recorded.

When analysing the contribution of individual taxa in subsequent parts of the section, attention should be drawn to the composition of sporomorph communities, their frequency and share of phytoclasts. All these elements indicate the changing dominant plant communities in the Tomisławice opencast section.

The oldest pollen community observed in samples 1–11 (Figs. 3 and 4) was described from massive detritic lignite (DLm) and in the lower part of the xylodetritic fractured lignite [XDLm (fr)]. This is dominated by swamp forest components with abundant *Nyssapollenites*. Pollen of shrub bogs – *Ericipites ericius, E. callidus, E. roboreus, Cyrillaceaepollenites* and *Ilexpollenites* have a large contribution. Pollen of mesophilous forests with *Tricolporopollenites pseudocingulum*, *Faguspollenites* and *Quercoidites henrici* is constant but not very numerous. The remaining components of the community are pollen of a *Pinuspollenites* coniferous forest.

The higher part of the section (samples 12–25) contains a fairly uniform pollen community and is composed of several lithotypes of lignite: xylodetritic fractured [XDLm (fr)], detroxylitic massive (DXLm), xylodetritic (XDLm) and massive detritic (DLm). An important role is played by the assemblage of shrubs with the dominant pollen of *Ericipites ericius, E. callidus* and *E. roboreus*. Numerous spores of *Stereisporites* and *Distancoraesporis* spores were seen. *Nyssapollenites* pollen is the dominant element in the swamp forest but is less numerous than in the older assemblage except for samples 13 and 20. *Alnipollenites verus, Inaperturopollenites concedipites* and *I. dubius* pollen have a small contribution in this still important community. In the community characteristic of mesophilous forest there occurs *Tricolporopollenites pseudocingulum* and *T. dolium* pollen, observed in the lower part (samples 13–15). The thermophilous taxa that appeared in this part include *Araliaceoipollenites euphorii, Cupuliferoipollenites oviformis* and *C. pusillus*. Pollen of *Quercopollenites* sp., *Q. asper* and *Faguspollenites* was also present in the mesophilous forest community. The content of pollen riparian forest trees with *Fraxinipollis* was noticeable. At the boundary of lignite lithotypes between samples 14 and 15, as well as between 24 and 25, there occurred 2 cm thick laminae of very fine-grained sand; their presence (as breaks in peat sedimentation) did not cause any significant changes in the pollen record.

The youngest part of the pollen succession occurs in massive detritic (DLm) and xylodetritic lignite with a horizontal structure (XDLh, samples 26–35); this clearly differs from the two older assemblages. The importance of swamp forest and shrub thicket communities decreased. The trees of mesophilous forests with *Quercopollenites granulatus*, *Q. ruburoides* and *Faguspollenites* had the largest contribution. During the formation of xylodetritic lignite, phytogenic sedimentation ceased, which resulted in the separation (between samples 31 and 32) of this lignite lithotype by a 15 cm thick layer of grey clay. This episode is reflected in the composition of the palynomorph succession in sample 32 (from the lower part of the upper xylodetritic lignite with a horizontal structure). In this assemblage there occurred the water plants *Potamogetonacidites, Sparganiaceaepollenites, Sporotrapoidites* and *Nelumbopollenites*, as well as zygospores from the green algae Zygnemataceae family, including *Spirogyra* (extinct

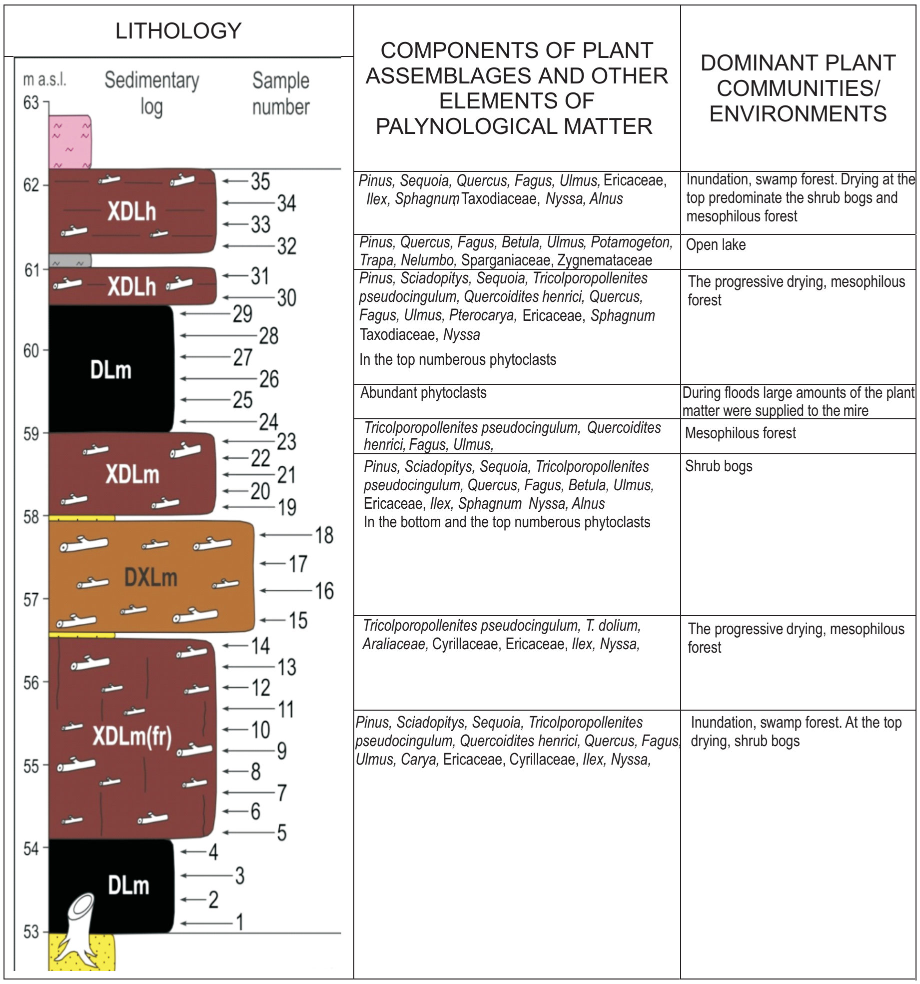

Fig. 4. The components of the plant assemblages and the dominant plant communities, with palaeoenvironmental reconstruction, in the Tomisławice opencast lignite mine

Explanation as in Figure 2

species *Ovoidites elongatus, O. grandis, O. ligneolus* and *O. spriggii*), while some specimens most probably related to desmid zygospores (*Planctonites stellarius*) played the main role. In addition, single specimens of *Sigmopollis pseudosetarius* and *Pediastrum boryanum*, as well as some leaf-spines of plants with submerged leaves, have been observed. At the same time, no pollen attributed to shrubs and swamp forests was recorded. Above this sample, the pollen spectrum (samples 33–35) was similar to that of sample 32 occurring below, with the pollen of mesophilous forest trees with *Quercopollenites granulatus, Q. ruburoides* and *Faguspollenites* of greatest importance. The significance of the swamp forest community with *Nyssapollenites* and *Alnipollenites verus*, as well as shrub thickets and the contribution of *Stereisporites* spores, increased at that time.

INTERPRETATION AND DISCUSSION

The results obtained allow us to reconstruct the development and succession of plant communities during the accumulation of the >9 m thick lignite seam. During the formation of this seam, the temperature and humidity levels were favourable for the accumulation of a huge mass of plant matter. Analysis of the changes in the composition of pollen assemblages shows that the key factor in the transformation of the dominant plant communities was changes in the soil moisture, manifested by fluctuations of the groundwater level.

In the oldest part of the section (samples 1–11), taxa indicative of swamp forest and shrub bog thickets dominate, with slight differences in pollen spectra between individual samples caused by humidity fluctuations, as recorded by the depletion of pollen assemblages in some samples (samples 10 and 11) and decrease in the share of mesophilous forest components, when a large role in the composition of palynological matter was played by abundant phytoclasts. The most numerous components of these communities were *Nyssa* and Ericaceae. The groundwater level was high enough for the peat-forming plant communities to persist for a relatively long time.

The mire was gradually drained and the mesophilous forest encroached upon it (samples 13–15), as recorded by an increased contribution of mesophilous forest pollen – i.e. the extinct species *Tricolporopollenites pseudocingulum* and *T. dolium*, as well as the presence of pollen taxa of plants with higher thermal requirements from the Castaneoideae subfamily and Araliaceae family. However, the dominant role in this assemblage was still played by pollen of shrub bog thickets and a slightly smaller role by the swamp forest.

Higher in the section, the contribution of pollen of mesophilous forest decreases (samples 16–22), the soil moisture increases and the peat-forming communities of the swamp forest and pollen of shrub bog dominate again. Representatives of the Sphagnaceae have a significant contribution. Towards the top of the section (samples 23 and 25), pollen spectra become poorer and phytoclasts clearly dominate. A brief episode of drainage and increased importance of the mesophilous forest community (sample 24) is recorded by high abundance and species diversity.

In the basal part of the next segment of the section (sample 26), the groundwater level was again higher and the peat bog community with Sphagnaceae peat moss was once more dominant. Stable conditions prevailed above (samples 27–31), favouring the development of mixed mesophilous forests with representatives of the Fagaceae family, the Fagoidae and Quercioidae subfamilies, and coniferous forests with *Pinus, Sciadopitys* and *Sequoia*. A brief episode related to the development of open lake sedimentation was recorded (sample 32) by the presence of pollen of aquatic plants (microremains of filamentous green algae from the Zygnemataceae family and the extinct species *Sigmopollis pseudosetarius*), which indicate the presence of freshwater conditions: shallow, stagnant or slowly flowing, and probably eutrophic waters (van Geel and Grenfell, 1996; Worobiec and Szulc, 2010; Worobiec, 2010, 2011, 2014 and literature cited therein). The presence of the planktonic algae *Pediastrum*, as well as pollen grains of aquatic plants, such as *Nelumbo* and *Trapa*, indicate that extended period(s) of standing water occurred. Moreover, the presence of leaf-spines of plants with submerged leaves also points to the occurrence of submerged (entirely under water) aquatic plants, such as the Alismataceae, Hydrocharitaceae or *Ceratophyllum*.

The topmost part of the section is terminated by a mesophilous forest with Quercoidae and Fagoidae (samples 33–35), which still play an important role in this community. The increase in humidity and encroachment of a swamp forest with Taxodiaceae, *Nyssa*, *Alnus*, as well as a significant contribution of mosses from the Sphagnaceae indicate the next stage of mire formation.

Reconstruction of the history of vegetation development and its succession recorded in lignite of the Tomisławice opencast mine indicates mire evolution (Fig. 4). In the lower part of the seam, within detritic and xylodetritic lignite, an episode of flooding of the peat accumulation area and the dominance of the *Nyssa* swamp forest can be observed. With slight fluctuations in water level and slight drainage, shrubs of Ericaceae and *Ilex* entered the area. The climate was stable, warm and temperate. Later, the mire further dried, its lateral range decreased, and the margin of the mesophilous forest with traces of thermophilous vegetation encroached more closely. The area of the former peat bog was once again flooded, but to a lesser extent than previously. The presence of a swamp forest with shrub plants predominance and the Ericaceae appearing was clear. Representatives of *Sphagnum* were quite abundant in the peat, indicating the development of a raised mire without groundwater supply; this was an episode of further climax drainage of the peat bog. A riparian forest entered the mire and a mesophilous forest was located in close vicinity, with trees characteristic of a warm temperate climate; at this stage further drying of the area took place. Peat sedimentation was interrupted by the appearance of an extensive open lake basin, associated with clay deposition. The presence of aquatic vegetation and freshwater algae related with this event is recorded in xylodetritic lignite occurring above the clays. Swamp forest vegetation was not recorded in this community while conifer pollen from a far distance reached the lake. Lignite-forming sedimentation in the Tomisławice opencast mine terminated with a community dominated by a swamp forest with a large contribution of *Sphagnum*. This shows that the lake waters were shallower, and a swamp forest re-entered the flooded area and then developed to the mesophilic mixed forest at the top.

COMPARISON OF THE TOMISŁAWICE PALYNOFLORA WITH RESULTS FROM PREVIOUS STUDIES IN THE KONIN LIGNITE BASIN

The palynological analyses of the Tomisławice section may be compared with earlier studies in the Konin region, such as the model palynological section from Gosławice in which, based on a pollen analysis of a 5 m thick section from the 1st Mid-Polish Seam, Mamczar (1960b) described middle Miocene strata. She distinguished three phases of vegetation development. At the base of the seam there is a rich community of swamp forest vegetation with *Nyssa* and Ericaceae, and with the contribution of pollen of mesophilous forests with *Tricolporopollenites pseudocingulum* and *Edmundipollis*. In the middle part of the profile herbaceous and swamp plants had a markedly higher contribution, thermophilous plants were not as common, while trees of coniferous forests with *Sciadopitys* gained significance. In the uppermost part of the seam, she observed a mosaic arrangement of plant communities, in which trees of mixed forests, swamps and shrubs grew in similar numbers. Such interpenetrating communities characterize a fluvial setting with rapidly changing water levels. Some similarities can be seen with the central part of the Tomisławice section (samples 13–25).

Ziembińska-Tworzydło (in: Kasiński et al., 2010) described a 10 m thick lignite section from the Jóźwin I open-pit, in which, on the basis of a very rich pollen community, she reconstructed plant communities from highly water-saturated to dry upland forests and described their natural ecological succession. The most important were the swamp forest community with Taxodiaceae-Cupressaceae, *Nyssa*, and Ericaceae and Cyrillaceae shrubs. Certain analogies can be observed in the basal samples of the Tomisławice opencast section (samples 1–11) in the section representing swamp forests and shrub bogs.

A different record was noted in the Jóźwin IIB section (Słodkowska and Widera, 2021) in an area of peat accumulation with various plant communities associated with high soil moisture. The presence of vegetation surrounding the lignite-forming marshes was also clearly visible. In this fairly uniform assemblage of microflora, a clear cyclicity was observed, with the natural succession of plant communities repeated three times. At the beginning of each cycle, in the depositional zone of the peat-forming basin, there was a high proportion of pollen from mixed mesophilous forest plants growing in dry and moderately moist areas located far from the mire. Varied forests with deciduous trees as well as evergreen forests occurred, among which families and genera with high thermal requirements had a significant contribution. The vegetation of these forests registers climate change, mainly temperature fluctuations.

Changes in the contribution of thermophilous components were not registered in the Tomisławice section, where the share of these elements was small and constant. During the existence of this peat-forming basin, climate oscillations were insignificant. Taking into account the distance of this section from the opencast mines of Jóźwin IIB, this is justified by the fluvial regime, as the peat bogs in the Jóźwin IIB (Pątnów IV) area developed in a zone with meandering river environments, while at Tomisławice peat accumulation took place in a zone of anastomosing or meandering river settings (Widera et al., 2021a).

The 3 m-thick palynological succession from the wall of the Adamów opencast mine shows little variability both in terms of changes in the contribution of thermophilous elements and in fluctuations of the hydrological conditions (Worobiec et al., 2021). Representatives of the Ericaceae, Cyrillaceae and Clethraceae families, as well as *Ilex* and *Myrica*, dominate the entire section. Based on their presence, these shrub communities were compared with the present-day pocosin wetland ecosystems which occur in the southeastern coastal plain of the USA (Worobiec et al., 2021). Sequoia pollen also had a relatively large contribution, reaching the highest values in the upper part of the section. Pollen of thermophilous plants and elements of a mesophilous forest, *Tricolporopollenites pseudocingulum*, *Quercoidites henrici*, and *Edmundipollis*, was of little importance. Similarities can be observed when comparing the Adamów section with the Tomisławice section. Components of shrub thickets with Ericaceae, *Ilex* and Cyrillaceae, and of the *Nyssa* swamp forest, are also quite numerous. However, the contribution of representatives of the Taxodiaceae family in the Tomisławice opencast mine is low. More prominent in this section is the presence of pollen from thermophilous taxa: *Tricolporopollenites pseudocingulum, T. dolium, Quercoidites henrici, Q. microhenrici, Cupuliferoipollenites oviformis, C. pusillus*, Araliaceae and *Edmundipollis*. Taking into account that the section analysed is thicker, the Adamów section can be compared with the lower part of the Tomisławice section, which was dominated by peat-forming phytocoenoses composed of representatives of swamp forests and shrub bogs.

In the Konin area, palynological studies of the 1st Mid-Polish lignite seam were performed on four boreholes in the Pątnów IV field (Sadowska and Giża, 1991). The authors focused on determining the age of the seam and characterizing the prevailing vegetation. Differences in the contribution of particular pollen genera and families were related to different stages of the plant community succession. The most important were trees of swamp forests with Taxodiaceae, Cupressaceae and *Nyssa*. At the time of the lignite seam formation, the ancient river valleys represented wet areas that were periodically flooded and then drained, on which shrubs with Cyrillaceae, Ericaceae, and Rosaceae predominated. Some similarities with the Tomisławice section can be observed, especially in its middle part, corresponding to the dominance of shrub communities.

Analysis of the palynological sites in the Konin area shows that different stages of the plant communities' succession were recorded in pollen diagrams, indicating their variability and mosaic character. Changes in the composition of plant communities depended on changing water conditions, without any palynostratigraphic significance, and an attempt to organize them chronologically is not easy. The largest number of thermophilous plants was described from the lower part of the Gosławice section, in the Pątnów sections and in the Jóźwin IIB section. The Jóźwin I and Adamów sections show some similarities, indicating the presence of extensive wetlands covered by swamp forests and shrub bogs. Analysis and comparison of these sites show that the Tomisławice section represents the declining episode of lignite-forming deposition in the Konin Basin, in which moderately warm-climate vegetation had the prevailing contribution, with a negligible share of highly heat-loving plants. Frequent water-level fluctuations in the substrate resulted in a variable contribution of plant communities that prevailed during the accumulation of the 1st Mid-Polish lignite seam, that formed synchronously across extensive river valleys.

CONCLUSIONS

The thick lignite seam described from the Tomisławice opencast mine was formed under fairly stable warm temperate climate conditions. Through the entire section, the pollen communities do not record an increased contribution of plant taxa with high thermal requirements. The flora was dominated by warm temperate and thermophilous species, without the participation of highly heat-loving vegetation.

The palynological spectra do not record significant climate changes and the observed differences in the composition of the communities indicate fluctuations in the groundwater level due to changes in the base level caused by eustatic oscillations. This caused the water level to fluctuate and resulted in flooding-drying cycles. The reason for frequent changes in the succession of plant communities in the Tomisławice section were frequent water level oscillations in the substrate.

Certain patterns can be observed in the succession of plant communities. Swamp forests with little drainage transformed into shrub bogs, which means that the marsh forest plants were replaced by peat bog vegetation with Cyrillaceae, Ericaceae, *Ilex* and *Sphagnum*. At that time, the margin of the mesophilous forest approached the mire, with a distinct contribution of trees of warm temperate climate: *Quercus, Fagus, Betula, Pinus* and *Sciadopitys*. This type of plant community transformation can be observed throughout the Tomisławice section.

Based on the presence of freshwater algae and pollen grains of aquatic plants in the deposits, an episode of sedimentation in an open, shallow lake was documented. This phenomenon may be associated with a significant rise in the ground- or surface waters level and a stage of swamp flooding, which resulted in the formation of an extensive lake.

The peat accumulation visible in the Tomisłowice opencast mine accumulated in basins associated with fluvial facies characterized by modest water flow, as indicated by the lack of evident levels of mineral interbeds within the dense lignite seams.

The mire succession and evolution was most influenced by changing water conditions, i.e. multiple fluctuations in the groundwater level in a dynamic river valley environment.

Our research indicates that the composition of the pollen spectrum is not influenced by the lithological type of lignite, which indicates that the lignite lithotype is shaped by post-depositional transformations of the organic lignite-forming matter, and the palynomorphs contained in it are a permanent element.

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APPENDIX 1

Percentage distribution of the palynomorphs and phytoclasts from the Tomosławice opencast lignite mine

Taxa	35	34	33	32	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1
Spores																																			
Baculatisporites		1.2		0.4		0.8	0.2													1.1				0.3		0.7									
Baculatisporites primarius														0.7			1.5	1.3																	
Distancoraesporis ancoris															0.6							0.4	3.6												
Distancoraesporis germanicus	2						1.0	0.3	0.9	3.6																									
Laevigatosporites haardti	1.2	3.5	3.3	2.1	0.5	0.6	0.8	0.6	0.6	0.3		1.0	4.2				0.5	2.5	1.3		1.1			0.3	1.5	0.7	1.0	1.5	2.2	1.6	3.0		0.6	1.0	2.4
Retitriletes										0.6																									
Stereisporites										5.2	2.9			7.3	7.2	6.9																			
Stereisporites cyclus						0.2				2.6					1.1										1.5										
Stereisporites involutus		12.4			3.6	1.5		1.1			5.9		8.3	4.0		5.7		3.8		7.4	1.9	1.3	1.5	8.9	3.8	2.1	1.0	1.8	1.1						1.1
Stereisporites macroides									0.9	3.9																									
Stereisporites minor		4.3			1.4	0.4	0.4			1.9		0.3		2.7	2.8	3.4		3.1	3.9	6.3	3.0	2.5		17.1				0.7		1.1	0.8			0.5	0.6
Stereisporites stereoides	3.2	14.0		0.8	5.9	1.1			1.4			1.2			3.3			1.9			0.7	1.7									0.8			0.7	0.9
Stereisporites validus										2.6																									
Toroisporis																															0.4				
fungal spores	+	+		+	+	+	+	+	+				+		+	+		+		+				+	+	+			+	+	+	+			+
fungal hyphae			+							+								+		+															
Gymnosperms																																			
Abiespollenites		1.2	0.7	1.7	0.7	3.8	1.7	3.4	6.9			2.8			2.8				3.2		1.5	0.4		2.2			0.7	1.1			0.4	1.1	1.1		
Cathayapollis								0.2		0.3																									
Cunninghamiaepollenites janinae												0.5			0.6	2.3	1.0																		
Cupressacites bockwitzensis	2	3.5		3.3	0.9	1.7	1.0	1.6	3.5	1.6		0.8			2.2	6.9		2.5											0.3						
Inaperturopollenites concedipites	2.4	2.7		1.7	1.1	1.1	1.0	0.5	3.8			1.2			0.6							0.4							1.4				0.8		
Inaperturopollenites dubius	2.4	8.5	7.3		6.1	6.4	1.5	0.8	6.9	3.6		1.5		2.7	3.3	3.4	2.0	3.1		2.1	0.7	0.8		4.1			0.7	0.7	1.9	0.8	2.3	1.1			0.6
Pinuspollenites	13.6	12.0	19.3	25.7	18.1	20.0	24.0	13.4	15.3	17.2	32.4	15.0	50.0	21.3	12.8	32.2	13.2	20.6	27.3	18.9	10.9	9.2	18.6	14.9	21.2	28.4	8.2	17.3	18.8	16.2	14.3	7.9	13.9	16.2	14.9
Sciadopityspollenites	1.2			0.8	1.4	1.9	3.3	6.7	5.2	4.9		3.5		2.0	3.9	2.3	15.6	21.3		6.3	10.5	5.4	5.7	7.6	3.0	5.7	2.1		1.6	4.1	2.6	7.2	3.0	1.4	1.3
Sequoiapollenites	8.4	4.3	1.3		3.2	9.3	5.8	4.4	12.1	2.9		1.3		3.3	2.8		1.0	1.9	6.5	16.8	2.2	1.3	1.0	4.8	1.5		0.7	2.6	4.3	1.9	2.3	15.2	7.5	0.7	1.5
Zonalapollenites gracilis						0.6		0.2	0.6			0.8									0.4	0.4							0.5					0.7	
Zonalapollenites igniculus							0.6					0.2																							
Zonalapollenites maximus						0.4																													
Zonalapollenites spinosus						0.4		0.5																											
Angiosperms																																			
Aceripollenites										0.3																	0.3	0.4	0.5					0.7	
Aceripollenites microrugulatus																			1.3																
Aceripollenites reticulatus																		0.6								0.7									
Alnipollenites verus	4		16.0	3.3	1.4		1.3	1.1	2.0	1.0	2.9	0.7		3.3	2.2	4.6	0.5		7.8	3.2	1.9	4.2		2.9			1.4	1.8		1.6	1.5	1.4	2.2	1.2	1.9
Araliaceoipollenites angki																		0.6																	
Araliaceoipollenites euphorii														0.7				0.6	0.6		3.0	1.7	2.1	0.3									0.3		
Araliaceoipollenites jadvigae		0.4		0.4																															
Araliaceoipollenites												0.3																							

reticuoides																																			
Arecipites																																			0.2
Arecipites butomoides	0.4																																		
Caprifoliipites				0.4			0.2																							0.5		1.1		1.7	1.1
Caprifoliipites andreanszkyi										0.3		0.3																							
Carpinipites	2.4		4.0	4.6	4.3		0.6	1.2				5.0			0.6		0.5	2.5		1.1				1.0	1.5		1.7	1.1	0.5	0.5				0.7	1.3
Caryapollenites simplex		1.2		0.4	0.2		0.2	1.9				0.8							0.6					0.3				0.4		1.1	0.4	4.7		0.2	
Celtipollenites bobrowskae				0.4					0.3	0.3	2.9	0.5		0.7		3.4			0.6		0.4					0.7				0.3	1.1				0.2
Cornaceaepollis satzveyensis																					1.5					1.4			0.8				0.8		
Corylopsispollenites				0.4											0.6							0.4	1.0												
Cupuliferoipollenites oviformis			0.7		0.5					0.6															0.8			1.5							
Cupuliferoipollenites pusillus					0.5	0.2	0.2	0.5										0.6	0.6			0.4			1.5	0.7	0.3			0.8	0.8	0.4			0.6
Cyrillaceaepollenites brühlensis						0.4						0.8													1.5	1.4	2.1	0.4				1.1	1.1	1.2	1.7
Cyrillaceaepollenites exactus		0.4						0.2						0.7	1.1	1.1		1.3	1.9		1.9	0.4	2.1			2.1	1.4		1.1					0.7	1.1
Cyrillaceaepollenites megaexactus					1.1		1.0							4.0	3.9		0.5		1.3			1.7	1.5	1.0		3.5	4.1	1.1	2.2	5.8	3.8	2.9	3.6	6.7	3.7
Diospyrospollenites																											0.3								
Edmundipollis															0.6																				
Edmundipollis edmundi																													0.3						
Edmundipollis vitiosus			0.7																																
Ericipites callidus																																		0.7	1.7
Ericipites ericius	6.8	1.6	3.3		5.2	3.6	4.6	3.1	4.6	6.8	14.7	6.3	12.5	14.7	10.6	4.6	11.2	3.8	18.2	12.6	13.9	17.9	27.3	16.5	20.5	9.2	20.6	16.9	7.6	10.4	10.9	15.5	15.0	21.9	16.2
Ericipites roboreus															2.2				1.9	3.2	1.1		0.5	0.3			0.3	0.4	0.5	0.5	1.5		2.2	0.7	2.4
Eucommiapollis																							0.5				0.3		0.5	0.3	1.1			0.5	
Eucommiapollis minor												0.8																							
Faguspollenites	11.2	4.3		11.6	3.4	5.9	19.6	17.5	12.7	12.9	2.9	19.6		3.3	3.9	6.9			2.6		1.1		0.5	0.3	0.8	2.1	3.1	4.8	5.4	7.4	2.6	2.9	5.8	3.1	5.8
Fraxinipollis						0.2									0.6																				
Fraxinipollis oblatus							0.8	0.3						0.7	0.6		1.5	2.5			0.4	0.4							1.1				0.3		
Fraxinipollis sinuosimuratus					0.2												4.4				0.4							0.4	0.5			0.4		3.1	0.6
Graminidites			2.0									0.3						1.3																	
Ilexpollenites iliacus						0.2	0.4					0.7		1.3	1.1	1.1							0.5				0.3	1.1	1.4	1.4	1.9	7.6	6.4	6.2	6.5
Ilexpollenites margaritatus	2.4	1.6	2.7		0.7	0.2		0.6	0.6	2.9		0.7		2.0	2.2			1.9	3.2		1.9					0.7	1.7	1.1	1.1	2.2	2.3			1.9	2.2
Ilexpollenites propinquus		0.8	0.7		0.9		0.4	0.5				1.0		2.7	1.7		1.0	2.5	1.9		0.7	0.8	0.5	0.6		2.1		1.1	1.6	2.7		1.8	1.4	2.9	2.8
Intratricoropollenites instructus								0.2	0.3								0.5					0.8					0.7						0.3		
Iteapollis angustiporatus							0.2																										0.3		0.4
Juglanspollenites								0.5							1.7																				
cf. *Manikinipollis*																																		0.23753	
Momipites punctatus								0.3	0.3														1.0					0.7							
Myricipites bituitus				1.2	0.2			0.5							1.1						0.7		1.0	0.3				1.1	1.1					0.7	1.1
Nelumbopollenites				1.2																															
Nyssapollenites	9.2	1.2	18.7	1.2	4.5	5.1	3.3	3.6	5.8	6.5	8.8	1.5	8.3		7.8	2.3	27.8	6.9	9.1	8.4	7.9	10.8	18.6	8.6	35.6	27.7	26.8	25.0	22.8	24.5	27.1	11.6	16.3	13.8	7.1
Oleoidearumpollenites	0.4		0.7									0.3	4.2									0.8		1.0	0.8		1.4	0.4				2.9		0.5	
Oleoidearumpollenites microreticulatus											2.9																								
Parthenopollenites marcodurensis							0.2																												
Periporopollenites orientaliformis							0.2					1.5																							
Periporopollenites stigmosus	2	0.4		2.1	0.2	0.4	0.4	0.8	0.6														0.5				0.3		0.5	0.8			0.3	0.2	
Platanipollis ipelensis							0.2	0.2	0.3																										

Platycaryapollenites																				0.4														
Polyatriopollenites	1.2	1.6		0.4	0.5	0.2	4.2	3.6	0.6	0.3		0.8		1.3			1.0							0.3		2.1	1.0	0.7	0.3			0.4			0.2
Potamogetonacidites				2.5																															
Quercoidites henrici		0.8	0.7	1.2			2.7	1.2		1.3		4.3		4.0	3.9		2.4					1.3		0.3	0.8	0.7	1.4	2.2	3.8				0.8		3.9
Quercoidites microhenrici		0.4			0.2		0.6										1.0																		
Quercopollenites			6.0								14.7	6.8		3.3			5.4												0.5	1.6	4.9			2.4	
Quercopollenites asper																2.3		3.1		3.2	2.6		2.1	1.6										1.7	
Quercopollenites granulatus	8.4	2.3	3.3	5.0	14.3	19.5		8.0	8.1	4.9																									
Quercopollenites rubroides	13.2	8.1		15.8	16.8	11.9	9.4	10.1		5.8													1.0												
Reevesiapollis triangulus								0.2						0.7																					
Rutacearumpollenites					0.2															1.1															
Salixipollenites			1.3	1.7	0.5	0.2	1.0	1.4	0.9					0.7		2.3		1.3											0.8	0.5				0.5	
Sapotaceoidaepollenites			0.7																																
Sparganiaceaepollenites				0.4																															
Spinulaepollis arceuthobioides						0.4	0.2			0.3				0.7				1.3	1.3	1.1								0.4		0.8	0.4	2.2		0.7	2.8
Sporotrapoidites illingensis				0.4																															
Sterculiapollis reticuloides									0.3																										
Symplocoipollenites																																		0.2	
Symplocoipollenites vestibulum		1.2												0.7																					
Symplocoipollenites rarobaculatus							0.2																												
Tricolporopollenites dolium		3.1			0.2	0.2	0.4	0.8							1.1	3.4					4.1	10.8	2.1		0.8	0.7	1.7	1.8	1.4	2.7	1.1		1.7		
Tricolporopollenites fallax																	1.0																	0.5	0.4
Tricolporopollenites indeterminatus								0.2																											
Tricolporopollenites liblarensis																																		0.5	1.5
Tricolporopollenites mangiferoides																																			0.4
Tricolporopollenites pseudocingulum		2.3			0.5		2.7	4.1	0.6			7.3		5.3	5.0	3.4	4.9	3.1	1.3	5.3	21.7	22.1	6.7	2.9		5.0	11.7	7.0	5.7	5.5	9.4	9.0	13.3	1.2	6.1
Tricolporopollenites quisqualis																												1.1							
Tricolporopollenites scutulensis										1.0																									
Tricolporopollenites staresedloensis																																0.4			
Tricolporopollenites theacoides										0.3																			3.5	0.5					
Tricolporopollenites villensis												0.2														0.7				0.3	1.1	0.4	1.1	0.2	0.2
Corylopollis coryloides				0.8						0.3														0.3	1.5		0.3								
Trivestibulopollenites betuloides	1.2		5.3	3.3		0.4	1.3	1.1	2.3	2.9		0.7	8.3	4.7	2.2		1.0	1.9	3.2	2.1	1.5	1.7			0.8	0.7	1.4	1.5	1.6	0.8		1.1		0.5	1.1
Tubulifloridites				0.4																															
Ulmipollenites undulosus	0.8	1.2	1.3	5.4	0.5	0.2	1.9	3.1	1.7			8.6	4.2	0.7	1.7	1.1	1.0	2.5						1.3	0.8		0.7		0.5	0.3	0.8			1.2	1.1
Vitipites					0.2	0.2					8.8																				0.8				
Phytoplankton																																			
Ovoidites elongatus				++																															
Ovoidites grandis				+																															
Ovoidites ligneolus				+++																															
Ovoidites spiriggii				+																															
Pediastrum boryanum				++																															
Planctonites stellarius				+++																															

Phytoclasts																																			
brown wood debris	+++	++	+++	+++	++	+++	++	++	+++	+++	++	++	+++	+++	+++	+++	+++	++	++	++	++	++	++	++	+++	+++	+++	+++	++	++	++	++	++	++	++
black wood debris	+++	++	++		++	+++	++	++	++	++	++	+	+		++				+	++		+	+	+	+++	+	+	++	+++	+	+	+	++	++	++
cuticule	++	++	+++	+++	++	++						++	+++	+++	++	++	+++	++	++	++	++	++	+++	+++	+++	++	++	++	+	++	++	+++	++	+	++

APPENDIX 2

Fossil spores and pollen taxa recorded in the deposits from Tomisławice and their botanical affinity and palaeobotanical affiliation according to Stuchlik et al. (2001, 2002, 2009, 2014)

Fossil taxa	Botanical affinity	Palaeofloristic element
Spores		
Baculatisporites sp.	Osmundaceae: *Osmunda*	P/A
Baculatisporites primarius (Wolf) Pflug & Thomson	Osmundaceae: *Osmunda*	P/A
Distancoraesporis ancoris (Krutzsch & Sontag) Srivastava	Sphagnaceae	P/A
Distancoraesporis germanicus (Krutzsch) Srivastava	*Sphagnaceae*	P/A
Laevigatosporites haardti (Potonie& Venitz) Thomson & Pflug	Polypodiaceae, Davaliaceae	P/A
*Retitriletes*sp.	Lycopodiaceae: *Lycopodium*	P/A
Stereisporites sp.	Sphagnaceae: *Sphagnum*	P/A
Stereisporites cyclus Krutzsch	Sphagnaceae: *Sphagnum*	P/A
Stereisporites involutus (Doktorowicz-Hrebnicka) Krutzsch	Sphagnaceae: *Sphagnum*	P/A
Stereisporites macroides Krutzsch	Sphagnaceae: *Sphagnum*	P/A
Stereisporites minor (Raatz) Krutzsch	Sphagnaceae: *Sphagnum*	P/A
Stereisporites stereoides (Potonie& Venitz) Thomson & Pflug	Sphagnaceae: *Sphagnum*	P/A
Stereisporites validus (Doktorowicz-Hrebnicka) Grabowska	Sphagnaceae: *Sphagnum*	P/A
Toroisporis sp.	Cyatheaceae? Dipteridaceae? Pteridaceae? Lygodiaceae	P
Gymnosperms		
Abiespollenites sp.	Pinaceae: *Abies*	A
Cathayapollis sp.	Pinaceae: *Cathaya*	A1
Cunninghamiaepollenites janinae Stuchlik & Konzalová	Cupressaceae: *Cunninghamia*	A1
Cupressacites bockwitzensis Krtutzsch	Cupressaceae: *Cupressus arizonica*	A1
Inaperturopollenites concedipites (Wodehouse) Krutzsch	Cupressaceae: *Taxodium, Glyptostrobus*	P2/A1
Inaperturopollenites dubius (Potonie& Venitz) Thomson & Pflug	Cupressaceae: *Taxodium, Glyptostrobus*	P2/A1
Pinuspollenites sp.	Pinaceae: *Pinus sylvestris* type	A
Sciadopityspollenites sp.	Sciadopityaceae: *Sciadopitys*	A1
Sequoiapollenites sp.	Cupressaceae: *Sequoia, Sequoiadendron, Metasequoia, Cryptomretia*	A1
Zonalapollenites gracilis Krutzsch	Pinaceae: *Tsuga canadensis*	A
Zonalapollenites igniculus (Potonié) Thomson & Pflug	Pinaceae: *Tsuga*	A

Zonalapollenites maximus Krutzsch	Pinaceae: *Tsuga*	A
Zonalapollenites spinosus (Doktorowicz-Hrebnicka)Ziembińska-Tworzydło	Pinaceae: *Tsuga forresti*	A
Angiosperms		
Aceripollenites sp.	Sapindaceae: *Acer*	A
Aceripollenites microrugulatus Thiele-Pfeiffer	Sapindaceae, Hippocastanoidae: *Acer*	A
Aceripollenites reticulatus Nagy	Sapindaceae, Hippocastanoidae: *Acer*	A
Alnipollenites verus (Potonié) Potonié	Betulaceae: *Alnus*	P2/A
Araliaceoipollenites angki (Gruas-Cavagnetto) Słodkowska	Araliaceae: *Scheffleropsis angkae*	P2
Araliaceoipollenites euphorii (Potonié) Potonié	Araliaceae: *Acantopanax spinosus, Aralia cordata*	P/A1
Araliaceoipollenites jadvigae Słodkowska	Araliaceae: *Aralia elata, A.spinosa*	P2/A1
Araliaceoipollenites reticuloides Thiele-Pfeiffer	Araliaceae: *Hedera helix*	A1
Arecipites sp.	Amaryllidacae, Araceae, Arecaceae, Butomaceae	P/A1
Arecipites butomoides Krutzsch	Araceae, Arecaceae, Butomabeae	P/A
Caprifoliipites sp.	Adoxaceae: *Sambucus, Viburnum*	P2/A1
Caprifoliipites andreanszkyi Nagy	Adoxaceae: *Viburnum rhytidophyllum*	P2/A
Carpinipites sp.	Betulaceae: *Carpinus*	P2/A1
Caryapollenites simplex (Potonié) Raatz	Juglandaceae: *Carya*	P/A1
Celtipollenites bobrowskae Kohlman-Adamska & Ziembińska-Tworzydło	Ulmaceae: *Celtis*	P/A1
Cornaceaepollis satzveyensis (Pflug) Ziembińska-Tworzydło	Mastixiaceae: *Mastixia*	P
*Corylopsispollenites*sp.	Hammamelidaceae: *Corylopsis*	A1
Cupuliferoipollenites oviformis (Potonié) Potonié	Fagaceae: *Castanea, Castanopsis, Lithocarpus*	P2/A1
Cupuliferoipollenites pusillus (Potonié) Potonié	Fagaceae: *Castanea, Castanopsis, Lithocarpus*	P2/A1
Cyrillaceaepollenites brühlensis (Thomson) Durska	Cyrillaceae, Clethraceae	P
Cyrillaceaepollenites exactus (Potonié) Potonié	Cyrillaceae, Clethraceae: *Cyrilla, Purdiaea, Cliftonia, Clethra*	P
Cyrillaceaepollenites megaexactus (Potonié) Potonié	Cyrillaceae, Clethraceae: *Cyrilla, Purdiaea, Cliftonia, Clethra*	P
Diospyrospollenites sp.	Ebenaceae: *Diospyros lotus, D. kaki*	P
Edmundipollis sp.	Mastixiaceae, Cornaceae, Araliaceae	P/A
Edmundipollis edmundii (Potonié) Słodkowska & Ziembińska-Tworzydło	Cornaceae, Mastxiaceae: *Diplopanax*	P1
Edmundipollis grossularius (Potonié) Słodkowska & Ziembińska-Tworzydło	Araliaceae: *Aralia, Panax*	P/A
Edmundipollis vitiosus (Mamczar) Słodkowska & Ziembińska-Tworzydło	Araliaceae: *Aralia, Panax*	P/A1
Ericipites callidus (Potonié) Krutzsch	Ericaceae: *Calluna, Vaccinium*	A
Ericipites ericius (Potonié) Potonié	Ericaceae: *Calluna, Daboecia, Vaccinium*	A
Ericipites roboreus (Potonié) Krutzsch	Ericaceae: *Rhododendron, Andromeda*	A
Eucommiapollis sp.	Eucommiaceae: *Eucommia*	A1
Eucommiapollis minor Menke	Eucommiaceae: *Eucommia*	A1
Faguspollenites sp.	Fagaceae: *Fagus*	A
Fraxinipollis sp.	Oleaceae: *Fraxinus*	P/A

Fraxinipollis oblatus Słodkowska	Oleaceae: *Fraxinus americana*	A
Fraxinipollis sinuosimuratus (Trevisan) Słodkowska	Oleaceae: *Fraxinus*	A
Graminidites sp.	Poaceae	P/A
Ilexpollenites iliacus (Potonié) Potonié	Aquifoliaceae: *Ilex aquifolium, I. macrocarpa*	P/A1
Ilexpollenites margaritatus (Potonié) Raatz	Aquifoliaceae: *Ilex asptella*	P2
Ilexpollenites propinquus (Potonié) Potonié	Aquifoliaceae: *Ilex*	P/A1
Intratriporopollenites instructus (Potonié) Thgomson & Pflug	Malvaceae: Tilioidae: *Tilia*	P/A
Iteapollis angustiporatus (Schneider) Ziembińska-Tworzydło	Iteaceae: *Itea*	P
Juglanspollls sp.	Juglandaceae: *Juglans*	A1
Manikinipollis sp.	Asclepiadaceae, Periplocoidae	P/A1
Momipites punctatus (Potonié) Nagy	Juglancaceae: *Engelhardia, Alfaroa, Oeromunnea*	P2
Myricipites bituitus (Potonié) Nagy	Myricaceae: *Myrica gale, M. javanica*	P2/A1
Nyssapollenites sp.	Nyssaceae: *Nyssa*	P/A1
Oleoidearumpollenites sp.	Oleaceae: *Olea*	P2/A1
Oleoidearumpollenites microreticulatus (Thomson & Pflug) Ziembińska-Tworzydło	Oleaceae: *Olea*	P2/A1
Parthenopollenites marcodurensis (Pflug & Thomson) Traverse	Vitaceae: *Parthenocissus, Ampelopsis, Cayratia, Leea*	P/A1
Periporopollenites orientalifomis (Nagy) Kohlman-Adamska & Ziembińska-Tworzydło	Altangiaceae: *Liquidambar*	A1
Periporopollenites stigmosus (Potonié) Thomson & Pflug	Altangiaceae: *Altingia*, *Liquidambar orientalis*	A1
Platanipollis ipelensis (Pacltová) Grabowska	Platanaceae: *Platanus*	P/A1
Platycaryapollenites sp.	Juglandaceae: *Platycarya*	P2/A1
Polyatriopollenites sp.	Juglandaceae: *Pterocarya*	A1
Potamogetonacidites sp.	Potamogetonaceae, *Potamogeton*	P/A
Quercoidites henrici (Potonié) Potonié, Thomson & Thiergart	Fagaceae: *Quercus*	P2/A1
Quercoidites microhenrici (Potonié) Potonié, Thomson & Thiergart	Fagaceae: *Quercus*	P2/A1
Quercopollenites sp.	Fagaceae: *Quercus*	P2/A1
Quercopollenites asper (Thomson & Pflug) Kohlman-Adamska & Ziembińska-Tworzydło	Fagaceae: *Quercus*	A1
Quercopollenites granulatus Nagy	Fagaceae: *Quercus*	A1
Quercopollenites rubroides Kohlman-Adamska & Ziembińska-Tworzydło	Fagaceae: *Quercus*	A1
Reevesiapollis triangulus (Mamczar) Krutzsch	Malvaceae, Helicteroidae: *Reevesia*	P
Rutacearumpollenites sp.	Rutaceae: *Ptelea*	P/A1
Salixipollenites sp.	Salicaceae: *Salix*	A
Sapotaceoidaepollenites sp.	Sapotaceae	P
Sparganiaceaepollenites sp.	Sparganiaceae, Typhaceae	P/A
Spinulaepollis arceuthobioides Krutzsch	Santalaceae: *Areuthobium*	P
Sporotrapoidites illingensis Klaus	Lythraceae: *Trapa*	A1
Sterculiapollis reticuloides Stuchlik	Malvaceae, Sterculiaceae: *Sterculia, Melochia*	P
Symplocoipollenites sp.	Symplocaceae: *Symplocos*	P

Symplocoipollenites vestibulum (Potonié) Potonié	Symplocaceae: *Symplocos alata, S. crategioides*	P
Symolocoipollenites rarobaculatus (Thiele-Pfeiffer) Ashraf & Mosbrugger	Symplocaceae: *Symplocos lenormandiana*	P
Tricolporopollenites dolium (Potonié) Thomson & Pflug	Fagaceae?	?
Tricolporopollenites fallax (Potonié) Krutsch	Fabaceae: *Anagyris, Dalea, Taverniera*	P/A
Tricolporopollenites indeterminatus (Romanowicz) Ziembińska-Tworzydło	Hamamelidaceae: *Parrotia persica, Distylium*	P2
Tricolporopollenites liblarensis (Thomson & Pflug) Hochuli	Fabaceae: *Anagyris, Dalea, Taverniera*	P/A
Tricolporopollenites mangiferoides Słodkowska	Anacardiaceae: *Mangifera indica*	P1
Tricolporopollenites pseudocingulum (Potonié) Thomson & Pflug	Fagaceae, Styracaceae	P/A1
Tricolporopollenites quisqualis (Potonié) Krutzsch	Fabaceae	P/A
Tricolporopollenites scutelensis Kohlman-Adamska & Ziembińska-Tworzydło	Theaceae, Theeae	P
Tricolporopollenites staresedloensis Krutzsch & Pacltová	Hammamelidaceae: *Parrotia, Distylium*	P2
Tricolporopollenites theacoides(Roche & Schuler) Kohlman-Adamska & Ziembińska-Tworzydło	Theaceae, Theeae	P
Tricolporopollenites villensis (Thomson) Thomson	Fagaceae?	?
Triporopollenites coryloides Pflug	Betulaceae: *Corylus*	A
Trivestibulopollenites betuloides Pflug	Betulaceae: *Betula*	A
Tubulifloridites sp.	Asteraceae	A
Ulmipollenites undulosus Wolff	Ulmaceae: *Ulmus*	A2
Vitipites sp.	Vitaceae: *Vitis*	P2/A1