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Middle Miocene peat mire types from the Adamów–Konin Basin in central Poland: lithotype and sedimentological analysis in relation to palynological data

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ABSTRACT:

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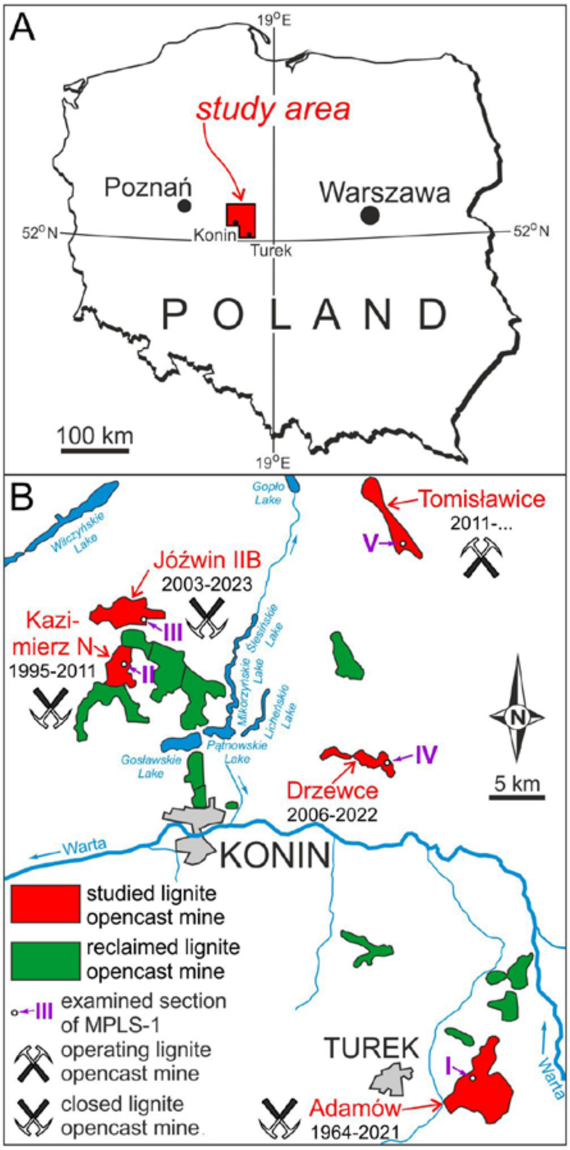
The first mid-Polish lignite seam (MPLS-1), mined in the vicinity of Konin and Turek in central Poland, has been subjected to multi-directional studies. These allowed for the deciphering of the environmental conditions in which relatively thick peat deposits were formed in the Middle Miocene. Research into organic matter alone does not allow for a complete determination of the mire type and its evolution. Much valuable additional information on this subject can be provided by a sedimentological study of siliciclastic interbeddings contained within the lignite seam. Therefore, this paper presents the results of low-rank coal lithotypes and clastic facies analysis. MPLS-1 from the Adamów–Konin Basin shows that the use of these two research methods can give satisfactory results. The lithotype analysis showed that sedimentary sub-environments (mire types: fen/open water, bush moor and forest mires, both relatively wet and dry) changed both vertically and laterally. On the other hand, sedimentological analysis of the siliciclastic sediments provides indirect evidence that the Mid-Miocene mires in central Poland existed in the vicinity of river channels. Their waters repeatedly flooded the mires, interrupted their evolution, and significantly increased the ash yield of MPLS-1. Finally, the presented results are in agreement with those obtained from palynological research.

Key words: Neogene; Lignite lithotype; Siliciclastic facies; Palynology; Fluvial system; Low-rank coal.

INTRODUCTION

Low-rank coal deposits still play a significant role in electricity production in Poland. In recent decades, its share in the national energy mix has fallen from over 35% to around 20% (Naworyta and Urbański 2025). The first mid-Polish lignite seam (MPLS-1), subjected to detailed research in this paper, is the youngest main and productive seam in the Miocene of Poland. It has only been exploited on an industrial scale in the Adamów and Konin sub-basins in central Poland (Text-fig. 1). In the first case, coal mining covered the years 1964–2021 (Widera *et al.* 2022a, 2024a), while, in the second case, it began in 1942 and will most likely cease at the end of 2026 (Kasztelewicz *et al.* 2025).

MPLS-1 has been mined in the Adamów and Konin coal mines for energy purposes. The Adamów Lignite Mine includes opencast mines located around the town of Turek, while the Konin Lignite



Text-fig. 1. Location map of the research territory. A – Study area on the map of Poland. B – Lignite opencast mines mentioned in the current study, the Adamów–Konin Basin in central Poland (drawn after maps provided by the Konin Lignite Mine and the Adamów Lignite Mine).

Mine includes opencast mines situated north of the town of Konin. A total of 17 opencast mines operated there, five of which were examined in detail in this study. It is worth noting that, at the beginning of 2026, only the Tomisławice lignite opencast mine remained (Text-fig. 1).

The examined MPLS-1 is classified as an ortho-lignite (ECE-UN, 1998) or a humic low-rank C coal because of its calorific value on the moist, ash free basis (Q_s^{maf}) <15 MJ/kg (ASTM D388 2005). In fact, the average net calorific value, recalculated for the total moisture basis (Q_i^r) for lignite mined in the Adamów–Konin Basin, is in the range 9.0–9.1 MJ/kg (Widera 2021). The mean random ulminite reflectance (R_r) is <0.3% and the carbon content on a dry ash free basis (C^{daf}) for MPLS-1 is in the range 60–70 wt% (Kwiecińska and Wagner 2001). In the case of ash yield on a dry basis (A^d), its content in MPLS-1 is very spatially diverse (6.5–69.8 wt%) and, on average, it is in the range 9.7–17.6 wt% (Chomiak 2020), while the average sulfur content is between 1.0 and 1.2 wt% (Kwiecińska and Wagner 1997; Bechtel *et al.* 2019, 2020). In micropetrographic terms, MPLS-1 from the study area is characterized by the dominance of huminite group macerals in the average range 75–89 vol.% on the mineral matter free basis. The rest are macerals of the liptinite and inernite groups, i.e., 4.5–9.4 and 3.5–7.0 vol.%, respectively (Macuda *et al.* 2011).

The depositional environment of peat, which later transforms into lignite and higher-ranking coals, can be reconstructed using various research methods. Among these, the most frequently used laboratory analyses are palynological, geochemical, stable isotopic and coal petrography (e.g., Stach *et al.* 1982; Esterle and Ferm 1986; Traverse 1988; Moore *et al.* 1991; Huhn *et al.* 1997; Lücke *et al.* 1999; Moore and Shearer 2003; Moore *et al.* 2006; Bechtel *et al.* 2007; Mach *et al.* 2013; O'Keefe *et al.* 2013; Çelik *et al.* 2017; Naafs *et al.* 2019; Oskay *et al.* 2019; Dai *et al.* 2020; Zdravkov *et al.* 2020, 2025; Utescher *et al.* 2021; Widera *et al.* 2021a; Wheeler *et al.* 2022; Kanduč and Markič 2024; Sattraburut *et al.* 2024; Kędzior *et al.* 2025; Yin *et al.* 2025). On the contrary, field studies of coal (i.e., lithotypes and sedimentological facies) are carried out relatively rarely, being limited to the description of their textural features. In relation to low-rank coals, investigations of the lithotypes have mainly been conducted by European and Australian researchers (e.g., Kwiecińska and Wagner 1997; Markič and Sachsenhofer 1997, 2010; Kolcon and Sachsenhofer 1999; Ticleanu *et al.* 1999; Holdgate 2005; Widera 2012, 2016a, 2021; Bielowicz 2013, 2016; Holdgate *et al.* 2014; Korasidis *et al.* 2016; Hann *et al.* 2020; Bik *et al.* 2026).

The examined lignite seam (MPLS-1) from the Adamów–Konin Basin is one of the best and most comprehensively investigated, not only in the Polish territory. At this point, it is sufficient to mention that MPLS-1 has previously been subjected to palynological (e.g., Sadowska and Giża 1991; Słodkowska and Widera 2021, 2022; Worobiec *et al.* 2021, 2022a–c, 2024, 2025) and geochemical studies (Macuda *et al.*

2011; Fabiańska and Kurkiewicz 2013; Detman *et al.* 2018; Bechtel *et al.* 2019, 2020; Bucha *et al.* 2020; Pytlak *et al.* 2021). MPLS-1 is also distinguished by the accurate recognition of low-rank coal lithotypes (Kwiecińska and Wagner 1997; Widera 2012, 2016a; Bielowicz 2013, 2016) and the two best-developed sets of opening-mode fractures (i.e., cleats) of all the low-rank coal seams exploited in Poland (Widera 2014a, b).

The results presented below are an expanded and more detailed supplement to those reported by the research team earlier (Widera *et al.* 2021a). In contrast to that paper, this study focuses primarily on the analysis of the lithotypes and facies constituting MPLS-1, and to a lesser extent on palynology. The number of sections examined has been increased, and ash yield fluctuations along these sections have been additionally taken into account. This has allowed for the identification of more flood episodes in the Middle Miocene peat mires than previously thought. However, the research of Widera *et al.* (2021a) omitted the results of detailed organic geochemical and stable isotope analysis, which had been obtained for three of the five sections studied (Bechtel *et al.* 2019, 2020). Due to the influence of external and local factors, such as floods, fluctuations in groundwater levels and changes in plant composition, the results of the mentioned research did not show any correlation with lithotypes (Widera *et al.* 2021a).

Therefore, the current paper presents the results of macropetrographic and sedimentological studies of MPLS-1. The primary goal is to decipher the palaeoenvironmental settings and mire types from which the lignite originated. This is achieved through macroscopic field observations of the lignite and siliciclastic interbeddings, i.e., in opencast mines in the Adamów–Konin Basin. The obtained results are then discussed and compared with selected palynological data from previous studies of MPLS-1.

GEOLOGY OF THE STUDY AREAS

Lithostratigraphically, MPLS-1 belongs to the Poznań Formation, which is the youngest main Neogene unit in central Poland. It is underlain by the Neogene Koźmin Formation and covered by Quaternary deposits. The Poznań Formation is divided into two secondary units: the lower Grey Clay Member and the upper Wielkopolska Member (e.g., Piwocki and Ziembińska-Tworzydło 1997; Widera and Klęsk 2025; Text-fig. 2). In general, >99 vol.% of the Grey Clay Member covers the examined MPLS-1 of Mid-Miocene age, which is also called the first Lusatian lignite seam (e.g., Widera 2012, 2014b; Bechtel *et al.* 2019, 2020) or the Konin lignite seam (e.g., Sadowska and Giża 1991; Widera 2007; Widera and Klęsk 2025). The remaining part of this member consists of 'grey clays' (up to 5-m thick), containing plant detritus and xylites, which occasionally lie on the roof of MPLS-1. Above this rests the upper Wielkopolska Member, which consists of multi-coloured clays, silts and muds ('green clays' and 'flamy clays'; up to 30-m thick) in the Adamów–Konin Basin (e.g., Klęsk *et al.* 2023; Wachocki *et al.* 2025). Finally, the Neogene is capped by a continuous 40–60-m thick sequence of Quaternary glaciogenic sediments, mainly tills, gravels, sands, and muds (Text-figs 2 and 3).

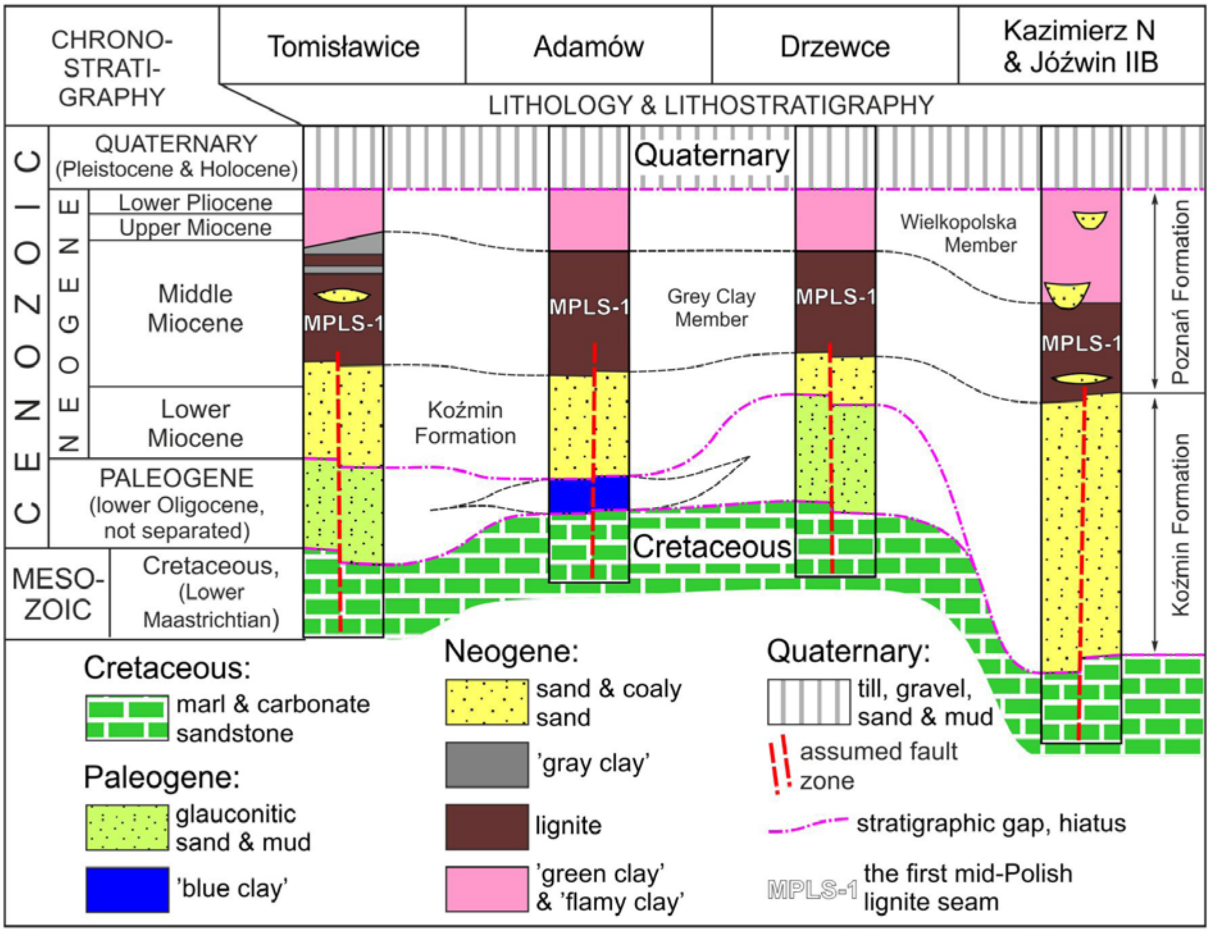
All of the investigated opencast mines cover relatively shallow grabens that are up to a few tens of metres deep (Text-fig. 3). They were tectonically active periodically in the Paleogene but, mainly, in the Neogene, including during the development of the Mid-Miocene mires in the study area (e.g., Kasiński and Piwocki 1992; Widera 2007, 2021; Jarosiński *et al.* 2009; Kasiński and Słodkowska 2016; Widera *et al.* 2021b). The deposits of MPLS-1 exploited in the Adamów–Konin Basin are rather small (<100 Mt of reserves) and characterized by an average thickness of 5.3–8.9 m, with a maximum thickness of 19.8 m. Most of the deposits cover the above-mentioned grabens but they also continue on their flanks (Text-fig. 3). Therefore, they represent both tectonic and epeirogenic genetic types, in varying proportions, encompassing very diverse Polish lignite deposits (Kasiński and Piwocki 2002; Widera 2016b).

MATERIAL AND METHODS

Archive and field materials

The simplified lithostratigraphic sections and geological cross-sections included in this paper are based on materials such as geodetic maps and borehole profiles (Text-figs 2 and 3), which were obtained from the geological archive of the Adamów and Konin lignite mines. However, research conducted in opencast mines provided most of the data used in the presented study.

Fieldwork was carried out in 2009–2024 during several field campaigns. At that time, sedimentological sketches of the lignite seam (MPLS-1) were done, with distinguished lithotypes and facies. A total of several hundred samples were also collected for fur-



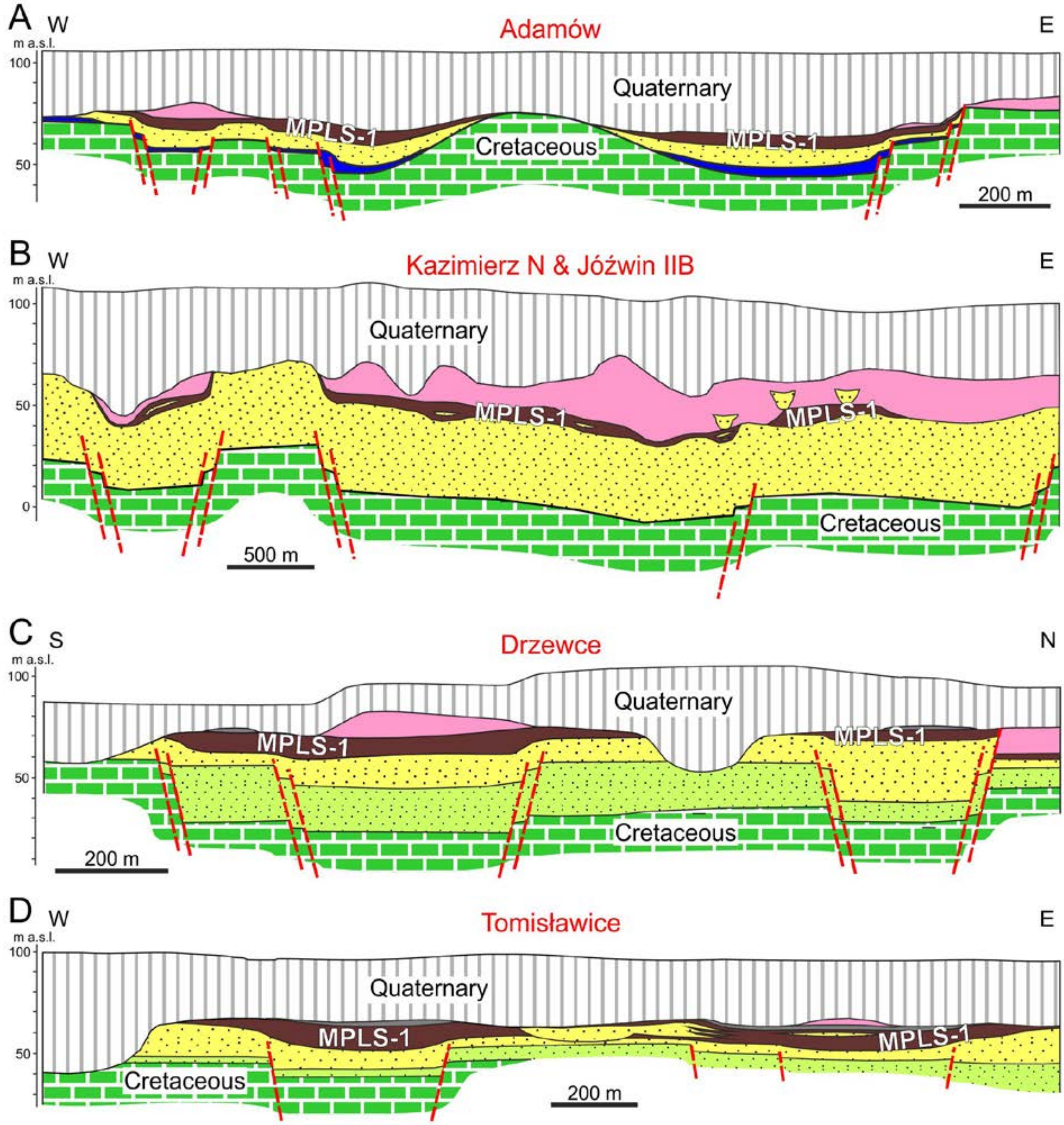
Text-fig. 2. Position of the examined first mid-Polish lignite seam (MPLS-1) against the background of the generalised Cenozoic lithostratigraphy of lignite-bearing areas in the Adamów–Konin Basin (after Widera 2021). For location of the examined opencast mines see Text-fig. 1.

ther laboratory tests (palynological, geochemical, isotopic, grain size and ash yield analyses), of which only 146 were used in the current study. To achieve the goals of this paper, in addition to the results from lithotype and facies analysis, the variability of ash yield along the studied sections of MPLS-1 is presented below. Lignite samples were ashed at a temperature of ~815 °C (ISO 2010) at the Institute of Geology, Adam Mickiewicz University, in Poznań, Poland.

Lithotype analysis

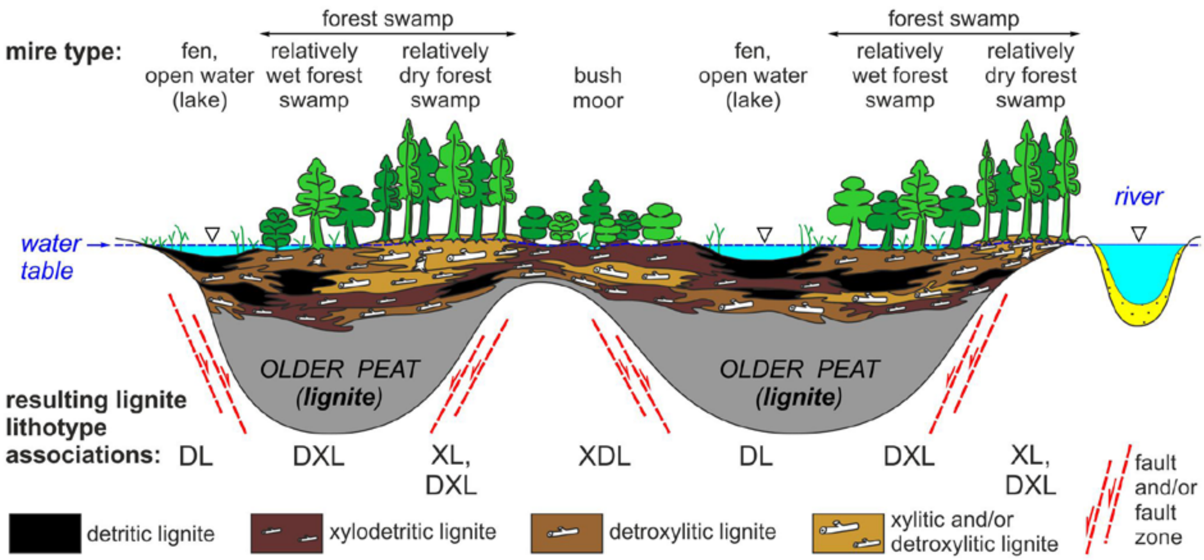
The macroscopic description of low-rank lithotypes can only be conducted in the field, i.e., on fresh coal mining profiles. This method gives the best results for ortho-lignites, where their textural (number of xylites, siliciclastic content, colour, etc.) and structural features (massiveness or stratification, deformations, etc.) are clearly visible. In older classifications, the term 'lithotype' was used to exclusively refer to the texture of a coal layer (Wolf 1988; ICCP 1993; Kwiecińska and Wagner 1997; Markič and Sachsenhofer 1997, 2010; Kolcon and Sachsenhofer 1999; Ticleanu *et al.* 1999), while its structure was mostly ignored (Table 1). Therefore, following Miall's (1977) lithofacies codification, a new codification of low-rank lithotypes was proposed, encompassing its texture and structure (Widera 2012, 2016b; cf. Tables 1 and 2).

In all of the above-mentioned classifications, the so-called '10% rule', recommended by ICCP (1993), was mainly used by European researchers dealing with ortho-lignites (e.g., Taylor *et al.* 1998; Flores 2014; Flores and Moore 2024). For example, the xylitic lithotype (XL) association (of various structures) contains >90% of xylites (i.e., fragments of fossilised



Text-fig. 3. Representative geological cross-sections of the lignite deposits exploited in the studied opencast mines from the Adamów–Konin Basin, based on borehole data and field observations. Opencast lignite mine area: A – Adamów; B – Kazimierz N and Jóźwin IIB; C – Drzewce; D – Tomisławice (compiled after Widera 2014a; Widera *et al.* 2017, 2022a, 2023; Chomiak *et al.* 2019, 2020; Chomiak 2020); for location of the examined opencast mines see Text-fig. 1 and for explanations see Text-fig. 2.

wood >1 cm) along the studied section of the low-rank coal seam. In the codification of low-rank lithotypes, texture is described with a capital letter and structure with a lowercase letter. It is worth noting that, in order to avoid confusion between the lithofacies/facies codification and the lithotype codification, the capital letter 'L' (= lignite) has been added in the latter case (Table 1). Finally, for more information on the evolution of low-rank lithotype nomenclature, the interested reader is invited to consult selected papers by Markič and Sachsenhofer (2010), Widera (2012), and Flores (2014).



Text-Fig. 4. Mire types and resulting lignite lithotype associations for the first mid-Polish lignite seam (MPLS-1) from the Adamów–Konin Basin in central Poland (modified after Teichmüller 1958, 1989; Widera 2012, 2021). For explanation of the lignite lithotype codes see Table 1; for other explanations see Text-figs 5–9 and the text.

The reconstruction of the initial mire types was carried out on the basis of the pioneering works of Teichmüller (1958, 1989). However, in the case of wet/dry forest swamp, the word ‘relatively’ was added, following the paper by Markič and Sachsenhofer (1997) (Text-fig. 4). This slight change makes the expression ‘relatively dry forest swamp’ more logical and linguistically correct than the expression ‘dry forest swamp’, which seems to be an oxymoron. Finally, the initial mire types obtained in this study were compared with the plant communities reconstructed palynologically for the same MPLS-1 two sections (IV – Drzewce and V – Tomisławice) from the Adamów–Konin Basin (Table 3; Słodkowska and Widera 2022; Worobiec *et al.* 2022a).

Sedimentological analysis

This part of the field research primarily covered the macroscopically visible clastic interbeddings within the studied MPLS-1. Less attention was paid to MPLS-1 under- and overburden. In order to simplify the field description, Miall’s (litho)facies codification (1977) was applied, with later additions by Zieliński (2014) and Widera *et al.* (2019), among others. This was limited to those textural and structural features that were found along the studied sections of MPLS-1 (Table 2).

For the fine-grained sediments analyzed, the commonly known and accepted terminology of Wentworth (1922) was used, i.e., clay (<0.002 mm), silt (0.002–0.063 mm), and sand (0.063–2.000 mm). A mixture of clay, silt and/or sand is referred to as ‘mud’ in this paper (Widera, 2023). Because the interlignite siliciclastic facies are often carbonaceous, the capital letter ‘C’ was applied in their codification, following Miall (1977, 2006). In turn, the structure of sediments is sometimes described using the lowercase letter ‘x’ (Zieliński 2014), which denotes cross-stratification or lamination types, such as planar, trough, low-angle, ripple, wavy, etc. (Table 2).

Palynological analysis

Samples were collected from the Adamów, Drzewce, Jóźwin IIB, and Tomisławice opencast mines for palynological analysis during fieldwork in 2017 and 2018, focusing primarily on MPLS-1. In this paper, the profiles from Drzewce (Section IV) and Tomisławice (Section V) were selected. This choice is justified by the fact that only in the case of these two sections (IV and V) the results of lithotype, sedimentological, and palynological analyses presented below were performed along the same MPLS-1 profiles. Furthermore, sedimentological and palynological analyses were performed on the same

<table>
<tr><th>ICCP 1993</th><th colspan="2">Wolf 1988; Markič and Sachsenhofer 1997; Kolcon and Sachsenhofer 1999</th><th colspan="2">Kwiecińska and Wagner 1997</th><th colspan="2">Ticleanu et al. 1999</th><th colspan="3">Widera 2012, 2016a</th></tr>
<tr><th>lithotype</th><th>lithotype</th><th>code</th><th>lithotype</th><th>code</th><th>lithotype</th><th>code</th><th>lithotype texture</th><th>code</th><th>lithotype structure – code</th></tr>
<tr><td>xylite-rich coal</td><td>xylitic coal</td><td>X</td><td>xylitic coal</td><td>WK</td><td>xylitic coal</td><td>XC</td><td>xylitic lignite</td><td>XL</td><td rowspan="9">massive – m
horizontal – h
fractured, folded, faulted – (fr, fo, fa)
nodular – (n)
gelified – (g)</td></tr>
<tr><td>matrix coal</td><td>detritic coal</td><td>D</td><td>detritic coal</td><td>WD</td><td>detrital coal</td><td>DC</td><td>detritic lignite</td><td>DL</td></tr>
<tr><td>-</td><td>detro-xylitic coal</td><td>D–X</td><td>detro-xylitic coal</td><td>WDX</td><td>-</td><td>-</td><td>detroxylitic lignite</td><td>DXL</td></tr>
<tr><td>-</td><td>xylo-detritic coal</td><td>X–D</td><td>xylo-detritic coal</td><td>WKD</td><td>weak xylitic coal</td><td>WXC</td><td>xylodetritic lignite</td><td>XDL</td></tr>
<tr><td>charcoal-rich coal</td><td>fusitic coal</td><td>F</td><td>fusitic coal</td><td>WF</td><td>charcoal</td><td>CH</td><td>fusitic lignite</td><td>FL</td></tr>
<tr><td rowspan="2">mineral-rich coal</td><td>-</td><td>-</td><td>-</td><td>-</td><td>clayey coal</td><td>CC</td><td>-</td><td>-</td></tr>
<tr><td>-</td><td>-</td><td>-</td><td>-</td><td>coaly clay</td><td>AC</td><td>-</td><td>-</td></tr>
<tr><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>weathered lignite</td><td>WL</td></tr>
<tr><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>bitumen-rich lignite</td><td>BL</td></tr>
</table>

Table 1. Comparison of international and older European classifications with the newest field macropetrographic classification of lignite lithotypes (modified after Widera 2021). Note the different nomenclature, spelling and codification of lithotypes, as well as the structural features included in the latest classification.

lignite samples. In the remaining cases (Jóźwin IIB and Adamów), there was no such agreement. In the Jóźwin IIB opencast mine, all investigations were performed along the same section, but on different samples from the same stratigraphic layers. In the Adamów opencast mine, however, samples for palynological analysis were collected several hundred metres north of the main section subjected to lithotype and sedimentological analysis. Therefore, for detailed information on palynological studies from these lignite opencast mines, the interested reader is asked to refer to other papers by the authors, i.e., from Jóźwin IIB (Słodkowska and Widera 2021) and from Adamów (Worobiec *et al.* 2021, 2022b, c).

The samples were processed using standard palynological maceration methods (Faegri and Iversen 1975; Moore *et al.* 1991). Samples from Drzewce were prepared at the Laboratory of the W. Szafer Institute of Botany PAS in Kraków (Worobiec *et al.* 2022a), while samples from Tomisławice were processed at the Laboratory of the Polish Geological Institute at the National Research Institute in Warsaw (Słodkowska and Widera 2022). Slides were prepared from all samples and examined for pollen grains and spores. The fossil taxa found were linked with modern plants (their nearest living relatives), mainly based on the 'Atlas of Pollen and Spores of the Polish Neogene' (Stuchlik *et al.* 2001, 2002, 2009, 2014).

Facies texture	
description	code
sand	S[a]
mud	M[b]
clay	Y[b]
coal (coaly)	C[a]
Facies structure	
description	code
massive	m[a]
horizontal	h[a]
cross-stratification	x[c]

Table 2. Codification of siliciclastic facies accompanying lignite lithotypes of MPLS-1 used in this paper.

[a] after Miall (1997); [b] after Widera *et al.* (2019); [c] after Zieliński (2014).

Plant communities were reconstructed by comparing spore and pollen taxa with known botanical affinities with contemporary vegetation, primarily from south-eastern North America, south-eastern Asia and the Caucasus, i.e., areas where the largest number of Miocene relics are currently found (e.g., Christensen 2000; Richardson 2003; Fang *et al.* 2011; Kayseri-Özer 2017). Additionally, the pollen data were supplemented by analyzing non-pollen palynomorphs (NPPs), such as algal and fungal micro-remains, to improve the reconstruction of the palaeoenvironment (Słodkowska and Widera, 2022; Worobiec *et al.* 2022a, 2024, 2025).

RESULTS

Section I – Adamów

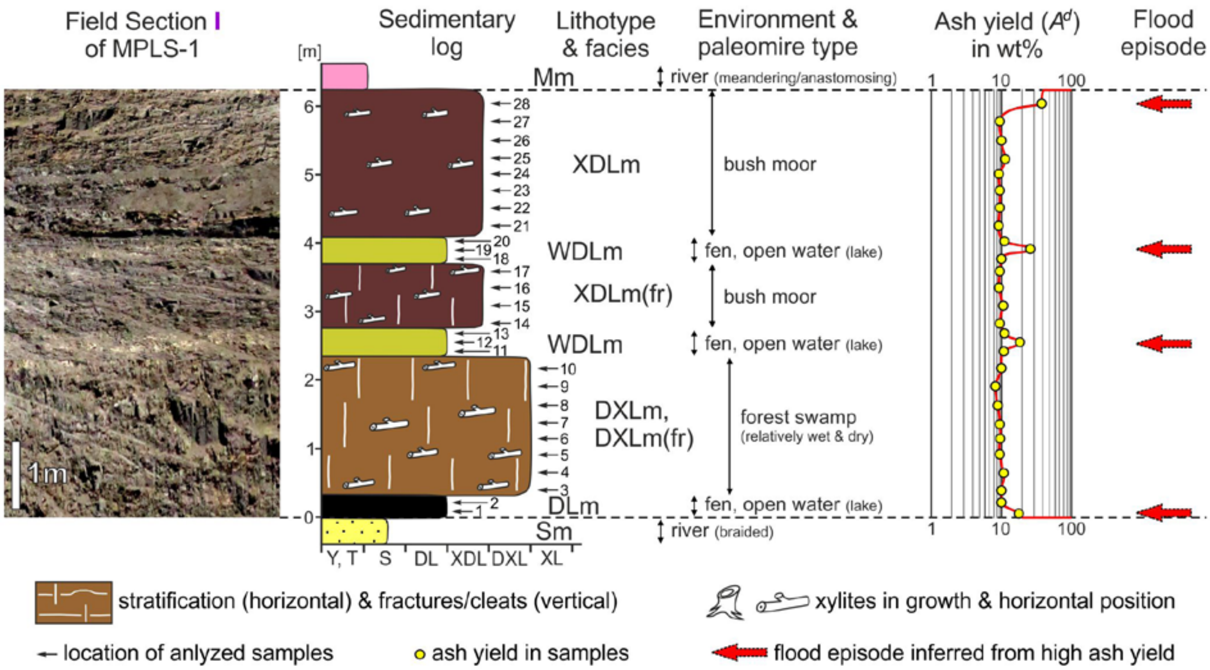
Description: The characterized Section I comes from the Adamów opencast mine (see Text-fig. 1). It is over 6-m long and includes four associations, consisting of six low-rank lithotypes: DLm, DXLm, DXLm(fr), XDLm, XDLm(fr) and WDLm (cf. Text-fig. 5 and Table 1). Less than 10 vol.% of xylites contain DLm and WDLm lithotypes. The xylites content is higher than plant detritus in the DXLm and DXLm(fr) lithotypes, while the opposite is true in the XDLm and XDLm(fr) lithotypes (Text-fig. 5).

The average ash yield in the 28 samples from Section I is 11.1 wt%. In most samples, ash yield is <10 wt% (A^d) but it is sometimes significantly higher. In samples 1, 12, 19, and 28 the ash yield is 18.2, 19.8, 27.0, and 39.1 wt% (A^d), respectively (Text-fig. 5).

<table>
<tr><th colspan="4">Section IV – Drzewce</th><th colspan="4">Section V – Tomisławice</th></tr>
<tr><th>sample number</th><th>lignite lithotype</th><th>mire type[a]</th><th>dominant plant community[b]</th><th>sample number</th><th>lignite lithotype</th><th>mire type[a]</th><th>dominant plant community[c]</th></tr>
<tr><td>36</td><td rowspan="12">XDLm(fr)</td><td rowspan="12">bush moor</td><td rowspan="36">shrub bog</td><td>36</td><td rowspan="4">XDLh</td><td rowspan="4">bush moor</td><td rowspan="4">swamp forest + shrubs</td></tr>
<tr><td>35</td><td>35</td></tr>
<tr><td>34</td><td>34</td></tr>
<tr><td>33</td><td>33</td></tr>
<tr><td>32</td><td>32</td><td>mud & clay</td><td>lake</td><td>open lake</td></tr>
<tr><td>31</td><td>31</td><td rowspan="2">XDLh</td><td rowspan="2">bush moor</td><td rowspan="8">mesophilous forest</td></tr>
<tr><td>30</td><td>30</td></tr>
<tr><td>29</td><td>29</td><td rowspan="6">DLm</td><td rowspan="6">fen, open water (lake)</td></tr>
<tr><td>28</td><td>28</td></tr>
<tr><td>27</td><td>27</td></tr>
<tr><td>26</td><td>26</td></tr>
<tr><td>25</td><td>25</td></tr>
<tr><td>24</td><td rowspan="2">WDLm</td><td rowspan="2">fen, open water (lake)</td><td>24</td></tr>
<tr><td>23</td><td>23</td><td rowspan="5">XDLm</td><td rowspan="5">bush moor</td><td rowspan="12">shrub + peat bog</td></tr>
<tr><td>22</td><td rowspan="15">XDLm(fr)</td><td rowspan="15">bush moor</td><td>22</td></tr>
<tr><td>21</td><td>21</td></tr>
<tr><td>20</td><td>20</td></tr>
<tr><td>19</td><td>19</td></tr>
<tr><td>18</td><td>18</td><td rowspan="4">DXLm</td><td rowspan="4">forest swamp (relatively wet & dry)</td></tr>
<tr><td>17</td><td>17</td></tr>
<tr><td>16</td><td>16</td></tr>
<tr><td>15</td><td>15</td></tr>
<tr><td>14</td><td>14</td><td rowspan="10">XDLm(fr)</td><td rowspan="10">bush moor</td></tr>
<tr><td>13</td><td>13</td></tr>
<tr><td>12</td><td>12</td></tr>
<tr><td>11</td><td>11</td><td rowspan="11">swamp forest + shrubs</td></tr>
<tr><td>10</td><td>10</td></tr>
<tr><td>9</td><td>9</td></tr>
<tr><td>8</td><td>8</td></tr>
<tr><td>7</td><td rowspan="3">XDLm</td><td rowspan="3">bush moor</td><td>7</td></tr>
<tr><td>6</td><td>6</td></tr>
<tr><td>5</td><td>5</td></tr>
<tr><td>4</td><td rowspan="4">DLm</td><td rowspan="4">fen, open water (lake)</td><td>4</td><td rowspan="4">DLm</td><td rowspan="4">fen, open water (lake)</td></tr>
<tr><td>3</td><td>3</td></tr>
<tr><td>2</td><td>2</td></tr>
<tr><td>1</td><td>1</td></tr>
</table>

Table 3. Comparison of the results of lithotype and palynological analysis performed for the same sections of the first mid-Polish lignite seam (MPLS-1) from the Drzewce and Tomisławice opencast mines, Adamów–Konin Basin in central Poland. Note the different nomenclature of mire types and dominant plant communities; compare with Text-figs 8 and 9.

[a] results of lithotype analysis shown in this paper; [b] results of palynological analysis obtained from Worobiec *et al.* (2022a); [c] results of palynological analysis obtained from Słodkowska and Widera (2022).



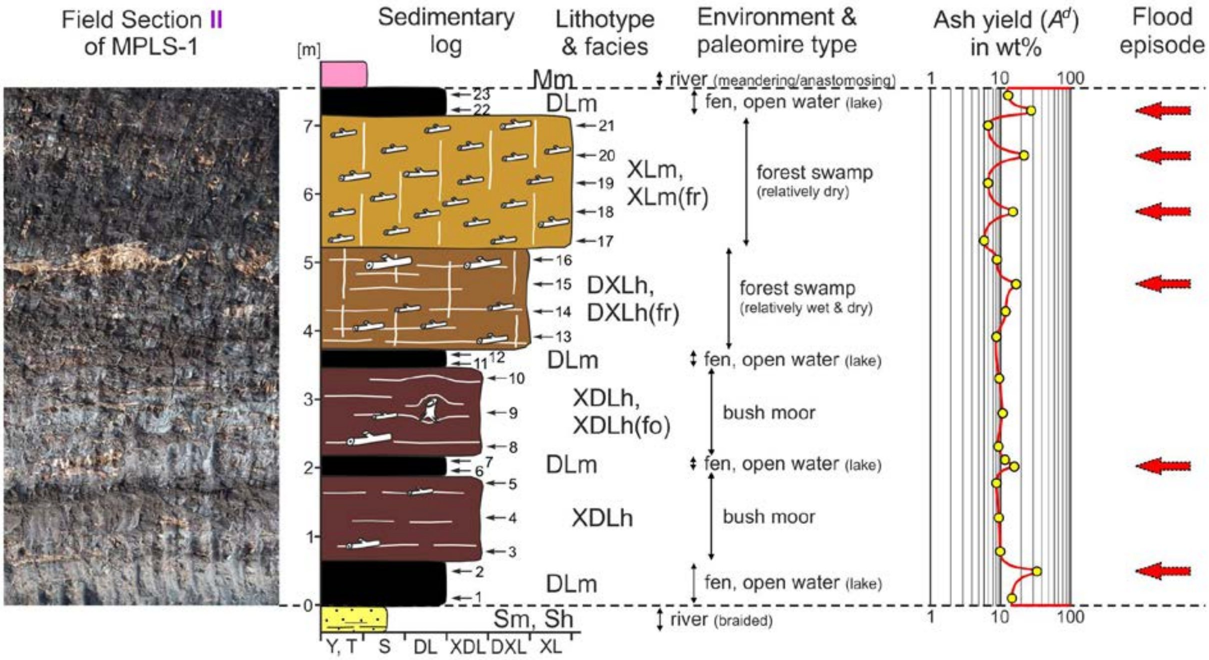
Text-Fig. 5. Macroscopic petrographic and sedimentological analyses of MPLS-1 in the Adamów opencast mine with palaeoenvironment interpretation. Note the significant increase in ash yield of individual samples within the same lignite lithotype; for location of the analyzed section see Text-fig. 1; for explanations of lithotype and facies codes see Tables 1 and 2.

Interpretation: The succession of lithotypes in the studied seam (MPLS-1) indicates the variability of hydrological conditions (groundwater or rainfall inputs) in the mire area and, as a result, the changing peat-forming plant communities (e.g., Teichmüller 1958, 1989; McCabe 1984; Moore 1989; Diessel 1992; Dai *et al.* 2020). Initially, herbaceous vegetation predominated (DLm) but then trees entered the mire, as evidenced by the predominance of xylites over plant detritus (DXLm and DXLm(fr)). The conditions were typical of a forest swamp, both relatively wet and dry. In the higher part of the interpreted Section I, the share of woody vegetation decreases (XDLm(fr), XDLm) and, periodically, becomes negligible (WDLm). This indicates the alternating occurrence of bush moor and fen (cf. Text-figs 4 and 5), i.e., a coastal-lake (limno-telmatic) mire <2 m deep (e.g., Diessel *et al.* 2000). In the last case (WDLm), the peat was elevated above the groundwater level for a long time, which led to its weathering.

The lack of macroscopically visible clastic interbeddings along Section I does not indicate that the mire development was interrupted by floods. However, the significantly increased ash yield in several samples allows for a different interpretation (Text-fig. 5). It can be stated that, in the initial and final phases (samples 1 and 28), the mire area was flooded by water coming from the surrounding river channels. In turn, within the weathered coal (WDLm; samples 12 and 19), the increased ash yield can be explained in at least two ways: as a flood episode or as a result of lignite weathering and its relative enrichment in mineral matter.

Section II – Kazimierz N

Description: Section II represents MPLS-1 from the Kazimierz N opencast mine (see Text-fig. 1). This section is up to 7 m long and covers four lithotype associations: detritic lignite (DL), xylodetritic (XDL), detroxylitic (DXL), and xylitic (XL). They include the following seven lithotypes: DLm, XDLh, XDLh(fr), DXLh, DXLh(fr), XLm, and XLm(fr) (cf. Text-fig. 6 and Table 1). Section II contains the most xylites of all the MPLS-1 sections studied. Furthermore, the amount of xylites increases from the floor to the roof of this seam.



Text-Fig. 6. Macroscopic petrographic and sedimentological analyses of MPLS-1 in the Kazimierz opencast mine with palaeoenvironment interpretation. Note the significant increase in ash yield of individual samples within the same lignite lithotype; for location of the analyzed section see Text-fig. 1; for explanations of lithotype and facies codes see Tables 1 and 2, and for other explanations see Text-fig. 5.

The ash yield in individual samples varies greatly and ranges from 4.4–33.4 wt% (A^d), with an average of 13.3 wt%. The ash yield is at its lowest in sample 17 and its highest in sample 2; it is also relatively high in the following samples: 6, 15, 18, 20, and 22 (Text-fig. 6).

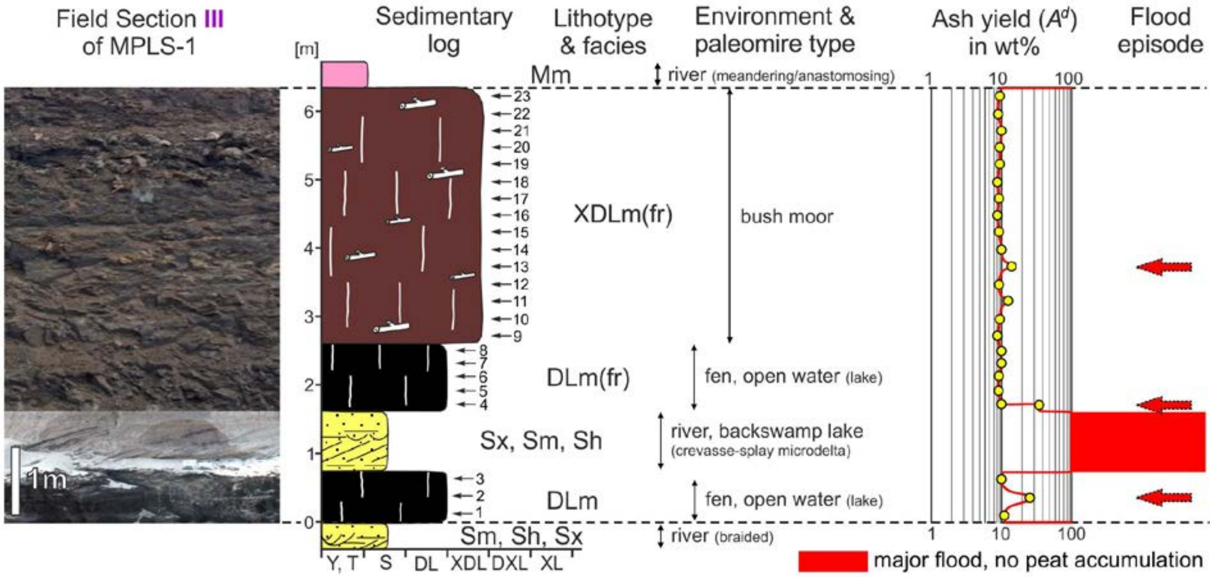
Interpretation: Section II starts, ends, and is interbedded with, detritic lignite (DL), which indicates an almost reed mire environment, such as fen or open water, i.e., a pond/lake. In other cases, the effect of terrestrialization – the opposite process to paludification – is visible as upwards through the section: DL → XDL → DXL → XL (Fig. 6). This general trend is interrupted by the occurrence of detritic lignite (DL) beds, which indicates periodic paludification of the mire area (e.g., Diessel *et al.* 2000; Opluštil *et al.* 2024; Kędzior *et al.* 2025).

Peaks of high ash yield (>17 wt% in samples 2, 6, 15, 18, 20, and 22) clearly contrast with the adjacent samples. In this case, and in the absence of other data such as peat weathering or fires, it should be interpreted as the result of at least several floods (Text-fig. 6; Chomiak 2020). In general, MPLS was formed as a topogenous, rheotrophic, low-lying mire (e.g., McCabe 1984; Moore 1989; Diessel 1992; Yin *et al.* 2025). Sample 17 is an exception to this, with an ash yield <5 wt% (A^d), indicating a raised, ombrotrophic mire (e.g., Schneider 1992; Moore and Shearer 2003).

Section III – Jóźwin IIB

Description: Among the sections selected for detailed analysis, Section III from the Jóźwin IIB opencast mine is characterized by the thickest siliciclastic interbedding. MPLS-1 is >6-m thick, of which ~1 m is covered by interlignite sands. In this case, the coal seam consists of only two associations (DL and XDL) and three lithotypes (DLm, DLm(fr), and XDLm(fr)). It should be noted that the share of xylites increases slightly towards the top of the section and all the coal layers have a fractured texture. On the other hand, the sandy bed is dominated by cross-stratification (Sx), planar cross-stratification in particular (Text-fig. 7).

It is clear that the sandy layer within MPLS-1, which contains trace amounts of organic matter, is composed of nearly 100 wt% of ash. On the contrary, coal samples include 8.6–37.0 wt% of ash, with an average of 9.9 wt% (A^d). The ash yield differs significantly from the average value in samples 2 and 4, and less in sample 13 (Text-fig. 7).



Text-Fig. 7. Macroscopic petrographic and sedimentological analyses of MPLS-1 in the Jóźwin IIB opencast mine with palaeoenvironment interpretation. Note the significant increase in ash yield of individual samples within the same lignite lithotype; for location of the analyzed section see Text-fig. 1; for explanations of lithotype and facies codes see Tables 1 and 2, and for other explanations see Text-fig. 5.

Interpretation: In the case of Section III, a slight trend towards terrestrialization is easily noticeable. The mire first evolved as a fen and/or lakeshore mire and then transformed into a bush moor: DL → XDL (cf. Text-figs 4 and 7). In turn, the fractures in MPLS-1, from the Jóźwin IIB opencast mine (i.e., cleats), are the best-developed in the studied seam exploited, not only those in Poland (Widera 2014a, b). Their genesis can be explained in various ways; in addition to tectonic causes, the low-rank coal lithotype, and ash yield also plays an important role (e.g., Laubach *et al.* 1998).

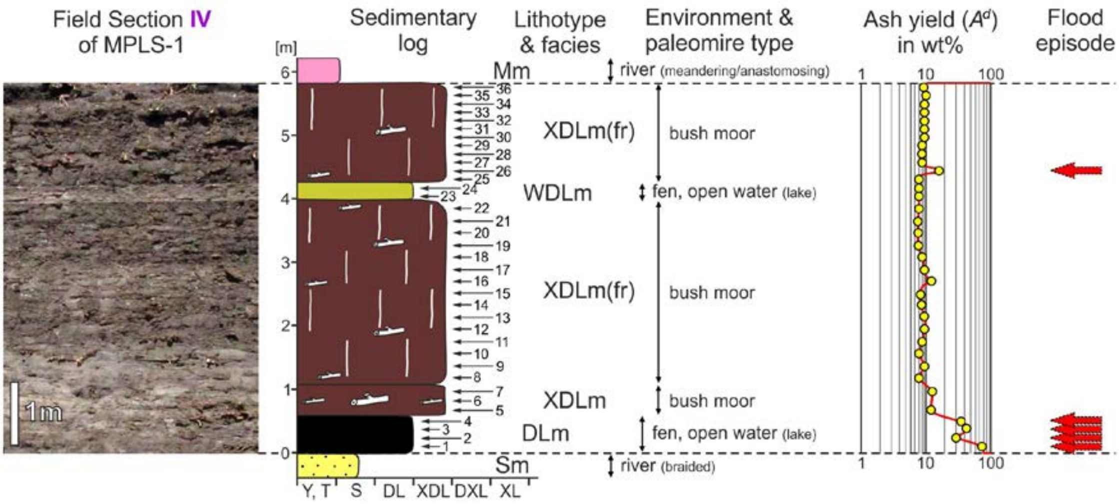
There is a high probability that samples 2 and 4 (containing 27 and 37 wt% of ash) are indicative of flooding of the mire by river water carrying a mineral load, i.e., fine sand grains. For sample 13, containing 14.5 wt% of ash (Text-fig. 7), the interpretation is uncertain, although a minor flood should not be ruled out. On the contrary, a 1-metre-thick layer of sand within MPLS-1 clearly proves that it was deposited by flood waters carrying large amounts of mineral load. These sands accumulated as crevasse-splay deposits in the extra-channel (overbank) area of the Mid-Miocene anastomosing and/or meandering river system, i.e., in the mire area where ponds and lakes existed. Taking into account the dominance of planar cross-stratification, extending up to hundreds of metres, they are interpreted as being typical of a crevasse-splay microdelta (Chomiak *et al.* 2019; Widera *et al.* 2022b, 2023; Wachocki *et al.* 2025).

Section IV – Drzewce

Description: Section IV presents MPLS-1 analyzed in the Drzewce opencast mine (see Text-fig. 1). This section is ~5.8-m long and is characterized by the least diverse composition of low-rank lithotypes among all the sections studied in this paper. It includes three lithotype associations: detritic lignite (DL), xylodetritic (XDL), and weathered detritic lignite (WDL). They contain the following four lithotypes: DLm, XDLm, XDLm(fr), and WDLm (cf. Text-fig. 8 and Table 1).

In most samples, the ash yield is close to, or below, 10 wt% (A^d). Its average value along the entire Section IV is 12.6 wt%, ranging from 6.7 to 66.0 wt%. The given mean value is mainly overestimated by the following five samples: 1–4 and 25, where the ash yield is in the range 31.9–66.0 and 14.0 wt% (A^d), respectively (Text-fig. 8).

Interpretation: The monotonous lithotype composition indicates little diversified hydrological conditions (e.g., McCabe 1984; Diessel 1992). In the mire area, where the studied seam was mined in the Drzewce opencast mine, only during the for-



Text-Fig. 8. Macroscopic petrographic and sedimentological analyses of MPLS-1 in the Drzewce opencast mine with palaeoenvironment interpretation. Note the significant increase in ash yield of individual samples within the same lignite lithotype; for location of the analyzed section see Text-fig. 1; for explanations of lithotype and facies codes see Tables 1 and 2, and for other explanations see Text-fig. 5.

mation of the DLm and WDLm lithotypes was peat deposited as a fen, or in the coastal zone of the lake existing within the Mid-Miocene mire. However, in the dominant part of MPLS-1 formation, bush moor conditions prevailed, as evidenced by the presence of lithotype XDLm(fr) (Teichmüller 1958, 1989; cf. Text-figs 4 and 8).

Section IV does not contain clastic interbeddings. It is certain that the formation of the floor part of MPLS-1 (the entire lithotype DLm; samples 1–4) was accompanied by frequent flooding episodes. This is also likely to apply to sample 25, when a small flood occurred in the mire. However, very high ash content in sample 1 (i.e., 66.0 8 wt%) means that it cannot be classified as lignite (>50 wt% of ash on a dry basis; ISO, 2018), but as carbonaceous (coaly) sands. The lithotype WDLm was interpreted above.

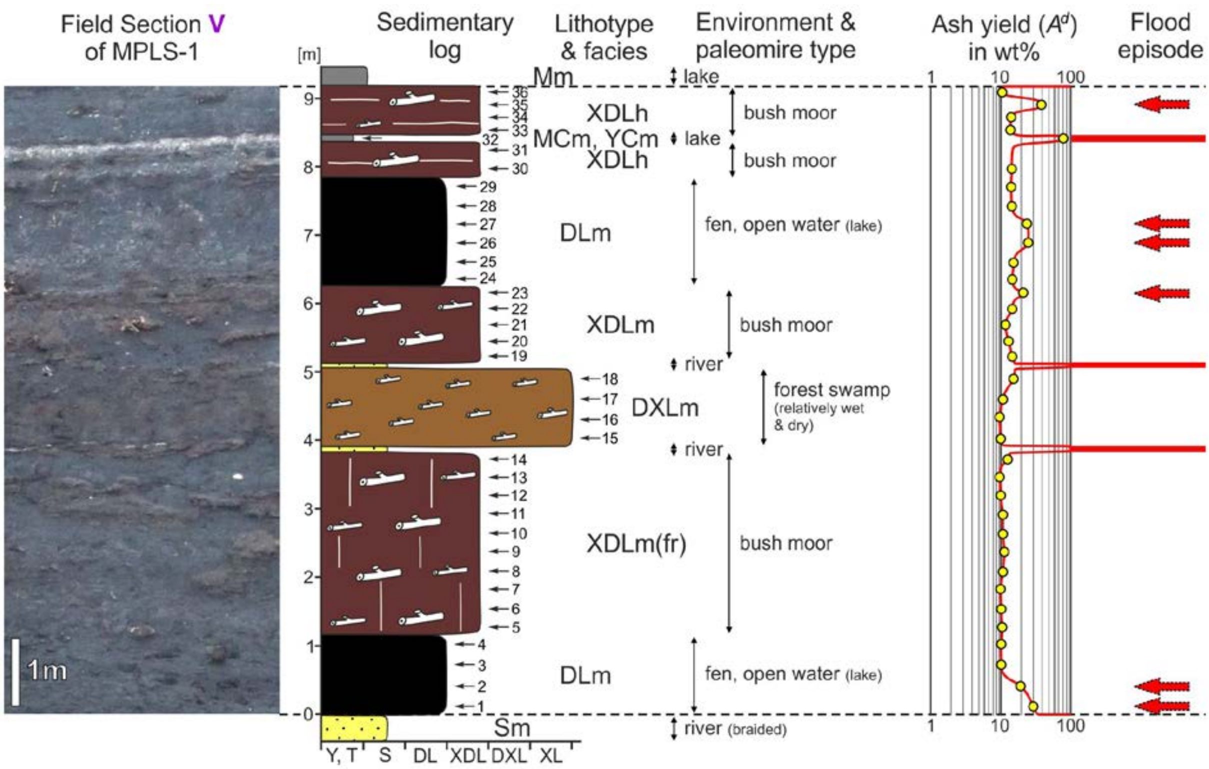
Section V – Tomisławice

Description: This section comes from the Tomisławice opencast mine, which is the only mine being exploited for the studied coal in May 2026 (see Text-fig. 1). It is the longest (up to 9.2 m) and is characterized by a diverse lithotype composition with the most siliciclastic interbeddings, both sandy and muddy-clayey. In this case, three associations (DL, XDL, and DXL) and five lignite lithotypes (DLm, XDLm, XDLm(fr), XDLh, and DXLm) can be distinguished (cf. Text-fig. 9 and Table 1).

There are two layers of fine-grained sand, up to 5-cm thick, and a layer of mud-clay, with a thickness of 20–30 cm in Section V. The ash yield in these sands is 100 wt%, while muddy-clayey sediments contain an average of 70.6 wt% ash. Moreover, although the average ash yield in the described section reaches 17.6 wt%, several samples reach values significantly higher than those in their neighborhood. Samples 1, 2, 23, 26, 27, and 35 should be mentioned here because ash yield ranges from 19.3 to 38.8 wt% (Text-fig. 9).

Interpretation: The bush moor (lithotypes XDLm, XDLm(fr), and XDLh), and fen and/or open water (lithotype DLm) mire types dominate in Section V. However, the middle part of this section can be interpreted as being typical of a forest swamp (lithotype DXLm), both relatively wet and dry (Teichmüller 1958, 1989; cf. Text-figs 4 and 9). This means that there are fewer xylites in the floor and roof of MPLS-1 than in its middle part.

The mire development in the vicinity of Section V was interrupted by floods. This is evidenced by both macroscopically visible intercalations of siliciclastics and a significantly increased ash yield in several samples (Text-fig. 9). The sandy layers are interpreted as the distal parts of the crevasse splays that encroached on the mire area (e.g., Widera 2016c; Widera *et al.* 2022b, 2023; Dziamara *et al.* 2023; Wachocki *et al.* 2025). In turn, the muddy-clayey layer is a relatively widespread (>1.5 km^2) sedimentary record of deposits



Text-Fig. 9. Macroscopic petrographic and sedimentological analyses of MPLS-1 in the Tomisławice opencast mine with palaeoenvironment interpretation. Note the significant increase in ash yield of individual samples within the same lignite lithotype; for location of the analyzed section see Text-fig. 1; for explanations of lithotype and facies codes see Tables 1 and 2, and for other explanations see Text-fig. 5.

in a long-lasting lake that existed in the mire area (e.g., Chomiak *et al.* 2020; Widera 2021). On the other hand, the increased ash yield in samples 1, 2, 23, 26, 27, and 35 may indicate several smaller floods, the waters of which contained less mineral load than in the above cases (Text-fig. 9). Thus, the examined MPLS-1 from the Tomisławice opencast mine accumulated entirely as a topogenous (e.g., Diessel 1992), low-lying (e.g., McCabe 1984) or rheotrophic mire (e.g., Moore 1989; Diessel *et al.* 2000; Flores 2014; Flores and Moore 2024).

Palynology of MPLS-1 from Drzewce and Tomisławice sections

Description: Samples from Drzewce (Section IV) contain numerous pollen grains from gymnosperms, including Cupressaceae (most likely related to *Sequoia*), *Pinus*, and *Sciadopitys*. Among angiosperms, Ericaceae, *Nyssa*, *Fagus*, *Quercus* (including *Quercoidites henricii*), *Tricolporopollenites pseudocingulum* (Fagaceae?, Styracaceae?), Cyrillaceae/Clethraceae, *Alnus*, and *Ilex* are the most common. The pollen from herbs, as well as fern and bryophyte spores, occurred regularly but in small quantities. Among non-pollen palynomorphs, there are freshwater algae (desmids and Zygnemataceae) and micro-remains of fungi, including epiphyllous, helicosporous, and rhizosphere fungi. The palynological profile from Drzewce shows variability in the abundance of individual plant taxa (particularly evident in the case of *Sequoia*, *Sciadopitys*, Ericaceae, and Cyrillaceae/Clethraceae), and these changes are of a fluctuating nature (Worobiec *et al.* 2022a).

In the case of the Tomisławice opencast mine, samples from Section V contain spores from peat mosses related to the Sphagnaceae family and ferns from the Polypodiaceae and Osmundaceae families. Gymnosperms are represented by pollen from the Pinaceae and Cupressaceae families. The pollen assemblage of angiosperms is characterized by *Nyssa*, *Tricolporopollenites pseudocingulum* (Fagaceae?, Styracaceae?), Ericaceae, *Ilex*, the Quercoidae subfamily, and small amounts of thermophilous plant species. Aquatic plants and non-pollen palynomorphs from freshwater green algae are also present (Słodkowska and Widera 2022; Worobiec *et al.* 2024).

Interpretation: The composition of the palynoflora from Drzewce generally indicates the presence of wetland and mesophilous vegetation; however, shrub mires were the dominant plant community throughout the entire sedimentation period (Worobiec *et al.* 2022a). Many of the recorded taxa, including representatives of the Ericaceae, Cyrillaceae, and/or Clethraceae families, as well as *Ilex*, *Myrica*, and some conifers (mainly *Pinus*), probably formed those communities. They were most similar to the modern pocosins that grow between river channels in the coastal plain of the southeastern United States (Richardson 2003). Riparian and swamp forests probably grew in the vicinity, in areas with medium to long periods of flooding. Mixed mesophytic forests grew in the areas which were not flooded (on elevations).

The fossil fungal assemblage found in Drzewce (Section IV) suggests that the area was covered by dense vegetation and had damp, swampy soils. It also indicates the presence of small, shallow water bodies with variable water levels or periodic reservoirs (Worobiec *et al.* 2022b). Similar conclusions can be drawn from the freshwater algae found in Section V. Fluctuations in the frequency of individual taxa, particularly among the conifers and algae, probably reflect changes in the water level and trophy. However, these changes were so minor that the shrub bog could persist as long as conditions which were favorable to peat-forming vegetation prevailed (Worobiec *et al.* 2022a).

Changes in the succession of plant communities in the Tomisławice Section V record flooding *via* drainage cycles caused by groundwater level oscillations. Peat bog accumulation took place in basins associated with river facies, as evidenced by the horizons of mineral deposits within MPLS-1. Episodes of flooding of the peat accumulation area and the domination of the *Nyssa* forest swamp are evident. With slight fluctuations in the water level and slight drainage, shrubs of Ericaceae and *Ilex* entered the area. When the mire was gradually drained, the mesophilous forest approached it, which is recorded by an increased contribution of the mesophilous the forest pollen *Tricolporopollenites pseudocingulum* and *T. dolium* (Fagaceae?, Styracaceae?), 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 was played by shrub mire thickets and, to a lesser degree, the forested mire (Słodkowska and Widera 2022). The presence of freshwater algae, aquatic plants, and an aero-aquatic fungus *Cancellidium intergraniferum* in sample 32 confirms a short episode related to the development of a shallow, freshwater lake (Słodkowska and Widera 2022; Worobiec *et al.* 2024).

Transformations of the plant community can be observed throughout the Tomisławice section. In the lower part of the lignite seam, within detritic and xylodetritic lignite, an episode of flooding of the peat accumulation area and the domination of the *Nyssa* swamp forest can be noted. With slight fluctuations in the water level and slight drainage, shrubs of Ericaceae and *Ilex* entered the area. Later, the mire further dried up, its lateral range decreased, and the margin of the mesophilous forest with traces of thermophilous vegetation approached closer in the upper part the bush vegetation. The area of the former of peat bog was once again flooded, but to a lesser extent than previously. Shrub plants predominantly dominated and the Ericaceae family began to be clearly present. Representatives of *Sphagnum* were quite numerous in the peat, proving the development of a raised mire, without groundwater supply. A riparian forest entered the mire and the mesophilous forest growing in its vicinity approached closer, with a clear contribution of trees characteristic of a warm temperate climate; at this stage further drying of the area took place (Słodkowska and Widera 2022).

Peat sedimentation in Tomisławice was interrupted by the appearance of a vast open lake basin, which is manifested by clay deposition (see Text-fig. 9). A short episode related to the development of open lake sedimentation was recorded as evidenced by the presence of pollen of aquatic plants: *Potamogetonacidites, Sparganiaceaepollenites, Sporotrapoidites* and *Nelumbopollenites*, and an aero-aquatic fungus *Cancellidium intergraniferum* as well as the occurrence of 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 (Słodkowska and Widera 2022; Worobiec *et al.* 2024). The presence of the planktonic algae *Pediastrum*, as well as pollen grains of aquatic plants, such as Nelumbo and Trapa, indicate that an extended period of standing water occurred. This evidence for the existence of the lake ends with the presence of mesophilous forest with Quercoidae and Fagoidae. 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 family prove the next stage of mire formation. It is the terminal part of the Tomisławice section (Słodkowska and Widera 2022).

DISCUSSION

Low-rank coal lithotype *versus* palaeomire type

The low-rank coal lithotypes distinguished within MPLS-1 from the Adamów–Konin Basin were formed in an anastomosing and/or meandering Mid-Miocene river system environment in central Poland (Widera *et al.* 2021a, b). The detritic lithotype association (DL) probably accumulated in the coastal zone of the lake or in open water (pond, lake), overgrown by reeds and sedges or aquatic plants, respectively. The xylodetritic association (XDL) was deposited in bush moors, while the detroxylitic and xylitic associations (DXL, XL) were deposited in forested mires; relatively wet (DXL) to relatively dry (XL), as affected by a fluctuating (high to low) groundwater table (Kwiecińska and Wagner 1997; Markič and Sachsenhofer 1997, 2010; Kolcon and Sachsenhofer 1999; Ticleanu *et al.* 1999; Widera 2012; Bielowicz 2013, 2016; Text-fig. 4). The last statement is also true for the association of the weathered lithotype (WL), in which palaeocharcoal fragments (fusitic lignite — FL) occurred more frequently than in other lithotypes (Widera 2016a, 2021; Bik *et al.* 2026).

Australian researchers (e.g., Holdgate *et al.* 1995, 2014; Holdgate 2005; Korasidis *et al.* 2016; Flores and Moore 2024) have a similar approach as European scientists, when distinguishing low-rank coal lithotypes. They decipher the depositional palaeoenvironment (i.e., initial mire type) based on the macroscopic features of brown coals (lignites), mainly the colour of coal bands but, also, their gelification, wood (xylite) content, and charcoal content. For example, the dark-coloured Australian brown coal lithotypes are referred to Polish (European) detritic lignites, while light-coloured and pale lithotypes may be equivalent to xylitic or weathered low-rank coal lithotypes distinguished within the MPLS-1 studied in this paper. Consequently, the medium-dark and medium-light lithotypes can be loosely correlated with the xylodetritic and detroxylitic lithotypes, respectively. European low-rank coals are not as varied in colour as Australian brown coals. A more detailed comparison of European and Australian low-rank coal lithotype classifications was carried out by Flores (2014).

Facies association *versus* depositional environment

The presence of siliciclastic interbeddings within MPLS-1 and the samples with high ash yields are of great practical and cognitive importance. Most often, these layers (<1.5-m thick; Widera 2021) are mined together with 'pure' coal beds and delivered to nearby power plants for electricity production. As a result, the calorific value of such coal drops drastically and, sometimes, becomes unsuitable for energy purposes, i.e., when its ash yield is >40 wt% (Chomiak 2020; Widera *et al.* 2022b; Dziamara *et al.* 2023).

The current state of MPLS-1 exploration allows us to confidently express the opinion that the exploited coal deposits were formed between the channels of a Mid-Miocene river. This was probably an anastomosing and/or meandering fluvial system, which requires further research; there are no exposed channel sediments (Widera *et al.* 2021a, b). On the contrary, the extra-channel (overbank) deposits of crevasse-splay sands are well known from numerous boreholes and outcrops in the studied opencast mines (e.g., Widera 2016c; Chomiak *et al.* 2019; Widera *et al.* 2023, 2024b; Wachocki *et al.* 2025). In the case of the muddy-clayey layer within MPLS-1, only one such bed (up to 0.8-m thick) is known from the Tomisławice opencast mine (see Text-fig. 9; Chomiak *et al.* 2020).

The aforementioned interbeddings of siliciclastics (sands, muds, clays, and coal-bearing sediments) indicate that the mire area was repeatedly flooded. In turn, the lateral extent of these mineral sediments reached the axial zone of the coal deposits and even covered them entirely. This may prove that the mires from which MPLS-1 was formed, and then exploited in the Adamów–Konin Basin, were mainly of the low-lying, rheotrophic mire type (e.g., McCabe 1984; Moore 1989; Diessel 1992; Diessel *et al.* 2000; Opluštil *et al.* 2024; Kędzior *et al.* 2025). Of course, this does not exclude the possibility of short-term drying of the mire surface by a relative lowering of the groundwater table, i.e., a raised mire of ombrotrophic type (e.g., Schneider 1992; Moore and Shearer 2003; Yin *et al.* 2025). This also confirms the presence of weathered and charcoal-rich lithotype (palaeocharcoal) in both Polish and global low-rank coal deposits (e.g., Kwiecińska and Wagner 1997; Holdgate *et al.* 2014; Korasidis *et al.* 2016; Widera 2021; Flores and Moore 2024; Bik *et al.* 2026). However, in the sections of MPLS-1 studied, charcoal fragments of very diverse sizes (from 1 mm to >20 cm) and uneven distribution were found in all characterized low-rank coal lithotypes. Furthermore, depending on habitat conditions, such as topography, both types of mires (rheotrophic and ombrotrophic) could occur in different locations at the same time.

Low-rank coal lithotype *versus* palynological analysis

In the middle part of the Mid-Miocene, the Adamów–Konin Basin area was located at least several hundred kilometres from the sea coast. Widespread mires developed at that time, leaving no palynological evidence of marine influence. As shown above, these mires existed adjacent to rivers. Since MPLS-1 in the study area has rich palynological documentation (e.g., Sadowska and Giża 1991; Worobiec *et al.* 2021, 2022a–c, 2024, 2025; Słodkowska and Widera 2021, 2022), the results of lithotype and palynological analysis need to be compared and discussed. For this purpose, only sections IV and V (Drzewce and Tomisławice) were selected (Table 3), as justified above (see Subsection 'Palynological analysis'). However, both sections differ in terms of lithotypes and plant communities. Section IV (Drzewce) is characterized by high monotony with variability in the percentage of individual plant taxa. On the contrary, section V (Tomisławice) shows high variability of plant communities and coal lithotypes, and their boundaries are often marked by thin siliciclastic layers (cf. Text-fig. 9 and Table 3).

Different, but generally very similar, terminology is used by petrographers and palynologists studying low-rank coal seams. This also applies to MPLS-1 from the Adamów–Konin Basin. Regardless of these differences, the reconstructed initial mire types and plant communities are very similar (Table 3). In the case of Section IV, based on the analysis of low-rank lithotypes, the dominant type of mire is bush mire with a layer of weathered coal in the upper part of MPLS-1. Palynologically, this section entirely covers the plant community characteristic of shrub mire, with a tendency to dry out towards the top (Worobiec *et al.* 2022a).

Apart from minor differences, a strong correlation between the interpreted mire types/plant communities can also be observed in the case of Section V (Table 3; Słodkowska and Widera 2022). However, the exception to this is the mesophilous forest, which can certainly not be represented by a fen and/or an open water environment. The presence of a mesophilous forest indicates that the forest has become close to the peat bog and spores and pollen have been transported to the peat bog by wind and surface water. Thus, caution should be exercised because allochthonous palynological taxa may sometimes lead to an incorrect reconstruction of the autochthonous plant community, as well as the initial mire type (e.g., Kasiński and Słodkowska 2016; Korasidis *et al.* 2016; Worobiec *et al.* 2025).

In order to identify these allochthonous/autochthonous taxa as accurately as possible, it is necessary to take into account the habitats from which the pollen-producing plants originate. For this purpose, the identified fossil pollen taxa must be linked to contemporary vegetation, which often poses difficulties because plants of the same genus can grow in different (wetland and mesophilous) habitats (Worobiec and Szynkiewicz 2016). On the other hand, palynology allows for the distinction between saltwater and freshwater mires (Bik *et al.* 2026), which cannot often be achieved through lignite lithotype and facies analysis alone. This is because palynological studies also use palynomorphs other than pollen (NPPs), such as algae, dinoflagellate cysts, fungi and others, to reconstruct the sedimentary environment (Worobiec *et al.* 2021, 2022a–c, 2024, 2025; Słodkowska and Widera 2022). In particular, fungal palynomorphs, which often represent autochthonous elements of wetland communities, are of significant importance for the reconstruction of the environment of lignite-forming communities (Worobiec *et al.* 2022a, b, 2024).

CONCLUSIONS

Fresh and relatively easily accessible exposures of the first mid-Polish lignite seam (MPLS-1) in the Adamów–Konin Basin (central Poland) opencast mines allowed various field studies to be carried out. Five sections of this seam were selected and detailed lithotype and facies analyses were conducted, with numerous samples being taken for further laboratory tests, including ash yield. These sections differ in lithotype composition, the presence or absence of siliciclastic interbeddings within MPLS-1, and the ash yield in subsequent samples.

Among the distinguished lignite lithotype associations, xylodetritic (XDL) and detritic (DL) lignite predominate. Detroxylitic (DXL), xylitic (XL) and weathered detritic (WDL) lignite occurs in smaller amounts within MPLS-1. In turn, fragments of fusitic lignite (palaeocharcoal) are scattered among the mentioned lithotypes but were not distinguished as a separate lithotype in this study. Moreover, individual lithotypes are characterized by various sedimentary (stratification, lamination) and deformational (fracturing, folding) structures. Within the examined

MPLS-1 there are interbedded siliciclastics and some samples are strongly enriched in mineral matter.

The initial types of mire were reconstructed, mainly bush moor for xylodetritic (XDL) and fen/open water for detritic (DL) lignite. In the area of these mires, major floods (crevasse-splay and lacustrine sediments) or minor flood episodes (increased ash yield) often occurred. Based on the results obtained from the lithotype and facies analysis, it can be stated with confidence that the Mid-Miocene mires in the Adamów–Konin Basin developed in the vicinity of river channels (backswamps), mainly as low-lying, rheotrophic mires but also, to a lesser extent, ombrotrophic peat bogs. Finally, excluding allochthonous floral components and terminological differences, the results of the lithotype–facies and palynological analysis of MPLS-1 are almost the same and complementary to each other for the two selected sections (IV from Drzewce and V from Tomisławice) of this lignite seam.

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