*Acta Geologica Polonica*, Vol. 74 (2024), No. 2, e14
DOI: 10.24425/agp.2024.150006

# The maximum extent of the Odranian Glaciation (Saalian, MIS 6) in the South Podlasie Lowland (SE Poland) in the light of sites with lacustrine deposits of the Mazovian Interglacial

MARCIN ŻARSKI[1], ANNA HRYNOWIECKA[2], ARTUR GÓRECKI[3], HANNA WINTER[1] and KATARZYNA POCHOCKA-SZWARC[1]

[1] *Polish Geological Institute-National Research Institute, Rakowiecka 4 Str., 00-975 Warszawa, Poland; e-mails: mzar@pgi.gov.pl; kpoch@pgi.gov.p; hwin@o2.pl*
[2] *Polish Geological Institute-National Research Institute, Marine Geology Branch, Kościerska Str. 5, 80-328 Gdańsk, Poland; e-mail: ahry@pgi.gov.pl*
[3] *Institute of Botany, Faculty of Biology, Jagiellonian University, Gronostajowa Str. 3, 30-387 Kraków, Poland; e-mail: artur.gorecki@uj.edu.pl*

ABSTRACT:

Żarski, M., Hrynowiecka, A., Górecki, A., Winter, H. and Pochocka-Szwarc, K. 2024. The maximum extent of the Odranian Glaciation (Saalian, MIS 6) in the South Podlasie Lowland (SE Poland) in the light of sites with lacustrine deposits of the Mazovian Interglacial. *Acta Geologica Polonica*, **74** (2), e14.

Based on the analysis of the geological context and palynological studies performed on lake and bog sediments in the Southern Podlasie Lowland, a new concept of the maximum extent of the Odranian Glaciation (Saalian, MIS 6) is presented for the study area. It is depicted by the Siedlce−Łosice−Kornica zone of end moraines, which so far was considered as stadial-rank or as the Wartanian ice sheet limit. To the south of this zone, near Biała Podlaska and in the Łuków Plain, there occur numerous sites with fossil deposits of the Mazovian Interglacial (MIS 11c). Sites with new documentation, i.e., Wólka Domaszewska, Kolonia Bystrzycka, Przytulin, Hermanów, and Skrzynka are located about 30 km to the south and 60 km to the west of the Biała Podlaska area. Palynological analysis unequivocally indicates the presence of a vegetation succession characteristic of the Mazovian Interglacial. In all sites, deposits of the Mazovian Interglacial are covered by lacustrine sediments of the Liviecian Glaciation (Fuhne, MIS 11b-MIS 10) or mineral sediments of the Vistulian Glaciation (Weichselian, MIS 2) and the Holocene. The sediments infill paleolakes carved in glacial tills of the Sanian 2 Glaciation (MIS 12). The lake sediments of the Mazovian Interglacial and the overlying biogenic and mineral deposits occur in the analysed sites directly below the surface. They are never covered by glacial deposits, which suggests that the Odranian ice sheet did not cover the study area. The location of the lake and bog sites with their geological analysis allow for the precise depiction of the eastern limit of the Odranian ice sheet lobe, which in the study area correlates with the limit suggested in the late 19th century. The Odranian ice sheet did not cover Southern Podlasie.

**Key words:** Odranian Glaciation (MIS 6) maximum extent; Mazovian Interglacial (MIS 11c); Palaeolakelands; Sanian 2 Glaciation (MIS 12); SE Poland.


Text-fig. 1. Maximum extents of glaciations in south-eastern Poland in historical terms (based on Małek 2011). A – Odranian Glaciation (Saalian, MIS 8); 1 – Siemiradzki 1889; 2 – Zaborski 1927, Mojski 1972a, b, Różycki 1972, 1980; 3 – Buraczyński and Wojtanowicz 1980/1981; 4 – Buraczyński 1986 (simplified). B – Warta Stadial /Podlasian /Middle Polish Glaciation or Warta Glaciation (MIS 6); 5 – Zaborski 1927, Terpiłowski 2001, Harasimiuk *et al*. 2004a, b, Żarski 2004, Godlewska 2014, Marks *et al*. 2018; 6 – Rühle 1970; 7 – Różycki 1972, 1980; 8 – Lindner 1988.

# INTRODUCTION

The last Pleistocene glaciation in the Polish Lowlands was the Odranian Glaciation (Saalian, MIS 6). Discussion on the maximum limit of its ice sheet has continued since the late 19$^{th}$ century. According to Siemiradzki (1889, p. 55) the extent of the "upper glacial till of the second glacial period" covered the Żelechów Heights (SE Poland) across to the Wieprz valley and the northern part of the Łuków Plain (Text-fig. 1).

According to Sawicki (1922), the maximum extent of the "Middle Polish glacier" was depicted by a line from the vicinity of Józefów in the Vistula valley in the south-west, through Chodel and Lublin, through Rejowiec to Dubienka upon Bug to the south-east.

The maximum extent of the Middle Polish ice sheet was depicted as sub-parallel till Chełm and in the Vistula valley till Zawichost by Zaborski (1927), based on detailed analyses of glacial forms and sediments representing the "youngest glaciation", as it was considered in those times (Text-fig. 1).

According to Zaborski (1927), the Lublin Upland was not covered by this glaciation, contrary to Sawicki (1922), who considered that the northern part of the Lublin Upland was covered by the Middle Polish ice sheet.

Zaborski's (1927) concept on the extent of the Middle Polish Glaciation has persisted with minor modifications of its course in numerous publications (e.g., Jahn 1956; Mojski and Rühle 1965; Mojski 1971, 1972a, b; Różycki 1972). According to Buraczyński and Wojtanowicz (1980/1981) and Buraczyński (1986), the ice sheet of the Odranian Glaciation covered the study area to the south of Chełm and Lublin, as far as Biłgoraj, thus expanding over most of the Lublin Upland (Text-fig. 1). However, according to most researchers, the maximal extent of the

| Zaborski (1927) | Różycki (1972) | Jersak (1973) | Ber et al. (2007) | Lindner and Marks (2012) | Stratigraphy in this paper | MIS |
|---|---|---|---|---|---|---|
| Eemian | Eemian | Eemian | Eemian | Eemian | Eemian | 5e |
| Podlasie St. | Warta St. | Wartanian Gl. | Wartanian–Odranian Gl. | Wartanian St.<br>Odranian Gl. | Odranian Gl. s.s.<br>with Wartanian St. | 6 |
| Middle Polish Gl. Maximum St. | Pilica Int. | Lublinian Int. | Lublinian Int. | Lublinian Int. | Lublinian Int. | 7 |
| | Middle Polish Gl. Odra St. | Odranian Gl. | Krznanian Gl. | Krznanian Gl. | Krznanian Gl. | 8 |
| | | | Zbójnian Int. | Zbójnian Int. | Zbójnian Int. | 9 |
| | | | Liviecian Gl. | Liviecian Gl. | Liviecian Gl. | 10 |
| | | | – | – | Early Liviecian Gl. | 11a–11b |
| Mazovian | Mazovian | Mazovian | Mazovian | Mazovian | Mazovian | 11c |

Table 1. Stratigraphy of the Quaternary in Poland between MIS 11 and MIS 5e according to different authors.

Odranian ice sheet conforms with that presented by Zaborski (1927) (e.g., Lindner and Marks 1995, 1999; Marks 2004a, b, 2011; Marks and Pavlovskaya 2006; Lindner *et al.* 2013).

Increasing recognition of Quaternary deposits in the Polish Lowlands has resulted in the sub-division of the Odranian Glaciation into two separate glaciations: the Odranian Glaciation *sensu stricto* correlated with MIS 8 and the Wartanian Glaciation correlated with MIS 6 (Jersak 1973; Różycki 1980; Lindner 1984; Table 1). Correlatives of these glaciations in the Central European Lowland in Germany were the Drenthe (MIS 8) and Warthe (MIS 6) glaciations (Litt *et al.* 2007; Head and Gibbart 2015; Table 2). A warm climatostratigraphic unit, i.e., the Lublinian/Lubavian Interglacial (MIS 7) was recognized between the Odranian Glaciation *s.s.* (MIS 8) and the Wartanian Glaciation (MIS 6).

In continental areas, the maximum ice sheet extent is usually marked by accumulated and piled-up end moraines, outwash fans, or terminal depressions (Schomacker and Benediktsson 2018). A very distinct end moraine zone occurs in the northern and eastern part of the Southern Podlasie Lowland, in the Siedlce Heights between Siedlce, Łosice and Kornica (Harasimiuk *et al.* 2004a, b). The maximum limits of the stadial-rank or Wartanian ice sheet were considered to occur in this area by numerous authors (e.g., Zaborski 1927; Różycki 1972; Mojski 1972a, b; Lindner *et al.* 1985, 1988, 1991; Lindner and Marks 1995; Marks *et al.* 1995; Albrycht 2001a, b, 2004, 2005; Terpiłowski 2001, 2021; Harasimiuk *et al.* 2004a, b; Małek 2004a, b, 2011; Marks 2004a, b; Żarski 2004; Godlewska 2014, 2015).

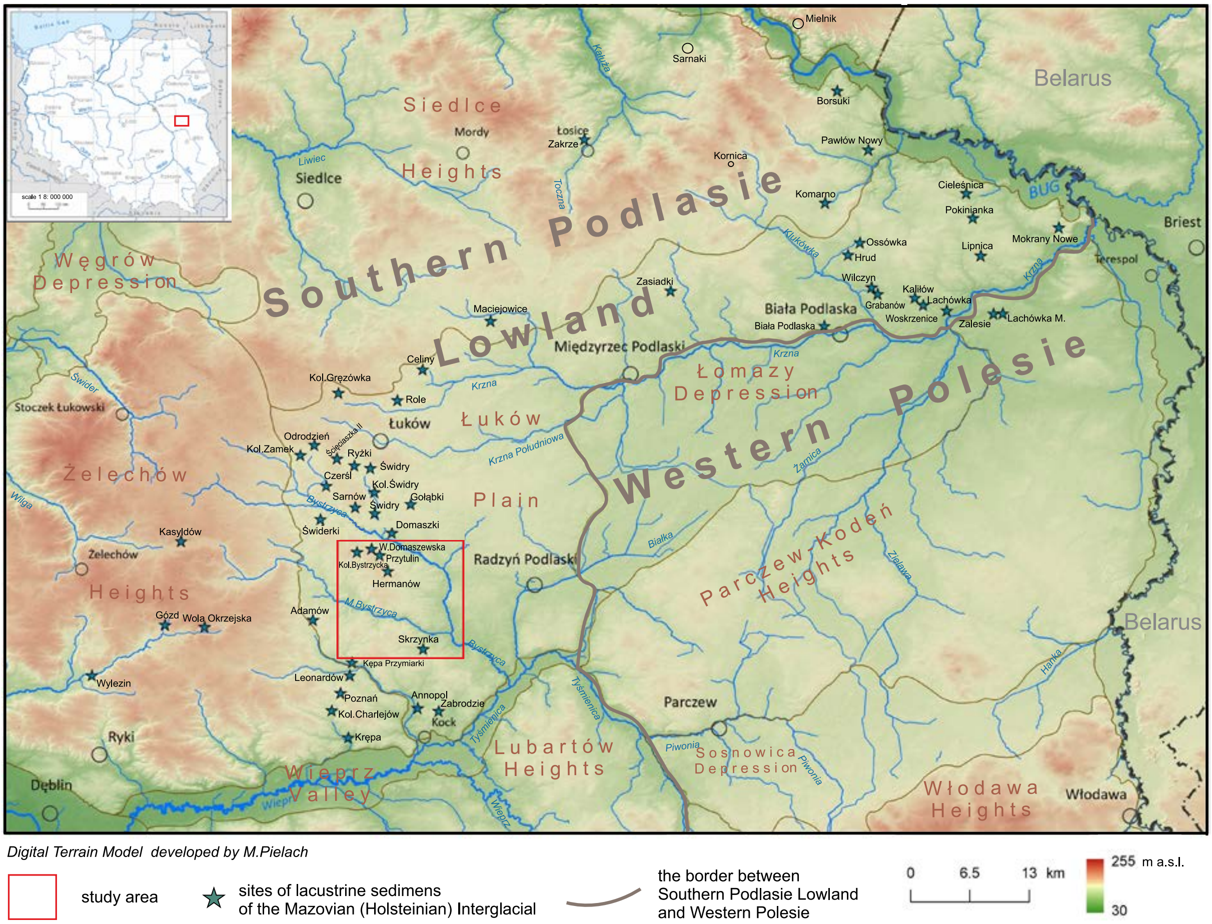
The earlier concept of one Odranian (Saalian) Glaciation reappeared in later studies on the palaeogeography of the study area, but it was then correlated with MIS 6 and not MIS 8 (Marks *et al.* 1995; Ber *et al.* 2007; Lindner and Marks 2012; see Table 1).

The Siedlce−Łosice−Kornica end moraine zone was considered to be the record of the recession phase of the Odranian ice sheet (Saalian, MIS 6), and the concept of the maximum extent of the Odranian ice sheet conformed with the idea of Zaborski (1927), i.e., as far as the vicinity of Chełm (Text-fig. 1).

Żarski (2006) was the first to formulate a hypothesis that southern Podlasie and Polesie were not covered by the Odranian Glaciation. Glacial tills of the Saanian 2 (Elsterian, MIS 12) Glaciation were recognized in the sub-surface of the area located to the south-west of Siedlce and Łosice, which was covered by the Adamów sheet of the Detailed Geological Map of Poland at the scale of 1:50 000 (Żarski *et al.* 2005a, b, 2009a; Żarski 2008, 2009). The concept of the maximum extent of the Odranian ice sheet near Siedlce was sustained by Marks *et al.* (2016), who revised some previous ideas. Such an interpretation of the maximum extent of the Odranian ice sheet was presented on the Geological Map of Poland at the scale of 1:500 000 (Marks *et al.* 2022). The maximum extent of the Odranian Glaciation near Siedlce was similarly presented on the Siedlce sheet of the map at the scale of 1:200 000 (Kucharska *et al.* 2019; Żarski and Kucharska 2019).

The course of the maximum extent of the Odranian Glaciation to the southwest of Siedlce is more problematic to depict due to the lack of distinct end moraine zones. Evidence critical for determining this limit in the area is the presence of sites with Mazovian Interglacial (MIS 11c) lake sediments that are not overlain by glacial deposits (Text-fig. 2).

This study aims to present the maximum extent of the Odranian (Saalian, MIS 6) ice sheet in the south-western part of the Łuków Plain being part of the Southern Podlasie Lowland (SE Poland) based on documented sites with lacustrine deposits recording the Mazovian Interglacial (MIS 11c) succession coupled with the geological context of the analysed strata. The basis for determining the age of the interglacial deposits was the results of palynologic




Text-fig. 2. Location of the sites of palaeobotanic studies of a Mazovian/Holsteinian paleolake in South Podlasie Lowland (Krupiński 2000; Nitychoruk *et al.* 2003, 2006; Nitychoruk and Gałązka 2006a, b, 2008, 2009; Żarski *et al.* 2009a; Marks and Karabanov 2017, 2018).

studies performed in five sites: Przytulin, Wólka Domaszewska, Kolonia Bystrzycka, Hermanów, and Skrzynka (Text-fig. 2).

## LAKE DEPOSITS OF THE MAZOVIAN INTERGLACIAL (HOLSTEINIAN, MIS 11C) IN THE STUDY AREA – STATE OF RECOGNITION

Sites with lake and bog deposits of the Mazovian Interglacial are of key significance for Pleistocene stratigraphy. They represent a benchmark horizon in the climatostratigraphic scheme for south-eastern Poland. Numerous sites with lacustrine and bog deposits (gyttja, peats, silts and peat shales) representing MIS 11c have been encountered directly below the surface in the area to the south of the Siedlce–Łosice–Kornica end moraine zone (Text-figs 1 and 2), and documented with geological, palaeobotanic and palaeofaunal studies.

Sites with Mazovian Interglacial sediments record the presence of paleolakes that developed after the Saanian 2 Glaciation (Elsterian, MIS 12; Żarski 2008, 2009; Żarski *et al.* 2009a) in depressions formed after melted-out dead-ice blocks (Małek and Pidek 2007; Pidek *et al.* 2011; Hrynowiecka *et al.* 2019; Górecki *et al.* 2022). In south-eastern Poland, most Mazovian Interglacial deposits accumulated in small basins located on the surface of fossil moraine plateaus or glaciofluvial plains from the Saanian 2 Glaciation. Their thickness does not exceed 12 m.

Palaeolakelands from the Mazovian Interglacial occur in south-eastern Poland in three regions (Text-fig. 2). Two of them are situated in the Southern Podlasie Lowland (Żarski *et al.* 2009), and the third – in Western Polesie (Hrynowiecka *et al.* 2014; Pochocka-Szwarc *et al.* 2024). In the first one, near Biała Podlaska (Siedlce

<table>
<tr><th rowspan="2">Aga ka BP</th><th colspan="4" rowspan="2">Stratigraphy</th><th colspan="2" rowspan="2">Poland</th><th colspan="2" rowspan="2">W Europe Germany</th><th colspan="2">E Europe</th><th rowspan="2">MIS</th></tr>
<tr><th>Belarus</th><th>Ukraine</th></tr>
<tr><td>11.7</td><td rowspan="11">Quaternary</td><td colspan="9">H o l o c e n e</td><td>1</td></tr>
<tr><td rowspan="2">130</td><td rowspan="10">Pleistocene</td><td rowspan="2">Late</td><td rowspan="2">North Polish Complex</td><td colspan="2">Vistulian*</td><td colspan="2">Weichselian</td><td>Poozerian</td><td>Valdy</td><td>2–5d</td></tr>
<tr><td colspan="2">Eemian</td><td colspan="2">Eemian</td><td>Muravinian</td><td>Pryluky (Horokhiv)</td><td>5e</td></tr>
<tr><td rowspan="8">424</td><td rowspan="8">Middle</td><td rowspan="7">Middle Polish Complex</td><td rowspan="6">Odranian s.l.</td><td>Odranian s.s. with Wartanian stadial</td><td rowspan="6">Saalian</td><td>Drenthe+ Warthe</td><td>Dnieperian II (Pripyatian)</td><td>Dnieper 2 (Tysmyn)</td><td>6</td></tr>
<tr><td>Lublinian (Lubavian)</td><td>Schöningen</td><td>Shklovian</td><td>Kaydaky</td><td>7</td></tr>
<tr><td>Krznanian*</td><td>?</td><td>?</td><td>Dnieper 1</td><td>8</td></tr>
<tr><td>Zbójnian</td><td>Reinsdorf</td><td>Smolenskian</td><td>Potagaylivka</td><td>9</td></tr>
<tr><td>Liviecian*</td><td rowspan="2">Fuhne</td><td rowspan="2">Cooling</td><td rowspan="2">Orel</td><td>10</td></tr>
<tr><td>Early Liviecian*</td><td>11a–11b</td></tr>
<tr><td colspan="2">Mazovian</td><td colspan="2">Holsteinian</td><td>Alexandrian</td><td>Zavadivka (Likhvin)</td><td>11c</td></tr>
<tr><td>South Polish Complex</td><td colspan="2">Sanian 2</td><td colspan="2">Elsterian</td><td>Berezinian</td><td>Tiligul (Krukienice)</td><td>12</td></tr>
</table>

Table 2. Chronostratigraphic correlation of Middle and Upper Pleistocene in: north-eastern Europe (Lit *et al.* 2007, Head and Gibbard 2015), south-eastern Poland (Lindner *et al.* 2006 (modified)), Marks *et al.* 2016 (modified)), Belarus (Velichkevich *et al.* (2001), Ukraine (Lindner *et al.* 2004a, b, 2006, 2007, Lindner and Marks 2008); and marine isotope stages (MIS). * area not covered by ice sheets.

Heights, Łuków Plain, and Łomazy Depression), geological and palaeobotanic studies of lake and bog deposits of the Mazovian Interglacial have been performed by numerous authors (e.g., Krupiński 1988, 1995, 1996a, b, 1997, 2000; Lindner 1988, 1996, 2005; Lindner *et al.* 1990, 1991a, b; Skompski 1991; Nitychoruk 1994, 2000; Bińka and Nitychoruk 1995, 1996; Lindner and Wyrwicki 1996; Albrycht *et al.* 1997; Bińka *et al.* 1997; Lindner and Marciniak 1997, 1998; Nitychoruk *et al.* 2005; Szymanek 2008, 2011, 2012, 2013; Pochocka-Szwarc *et al.* 2017).

The second region in the Southern Podlasie Lowland with a documented Mazovian palaeolakeland is located in its south-western part – in the vicinity of Łuków, Kock and Wola Okrzejska within the Łuków Plain and in the western part of the Żelechów Heights (Żarski *et al.* 2005a, b, 2009a; Małek and Pidek 2007; Pidek *et al.* 2011; Terpiłowski *et al.* 2014; Hrynowiecka *et al.* 2019; Górecki *et al.* 2022).

In the frame of the Adamów sheet of the Detailed Geological Map of Poland at the scale of 1: 50 000, the Kolonia Domaszewska, Kolonia Bystrzycka, Przytulin and Hermanów sites have been subject to expert palaeobotanic analyses of lake deposits, whose age was attributed to the Mazovian Interglacial (MIS 11c) (Krupiński 2004a, b, 2009; Żarski and Krupiński 2005; Winter 2006, 2008; Żarski *et al.* 2009b). A complete palaeobotanic expertise was prepared for Hermanów and Skrzynka (Hrynowiecka *et al.* 2019; Górecki *et al.* 2022).

The third region occurs in Western Polesie (Hrynowiecka *et al.* 2014; Pochocka-Szwarc *et al.* 2021; Pochocka-Szwarc *et al.* 2024). Single sites with lacustrine deposits of the Mazovian Interglacial have been documented in the Żelechów Heights: Wylezin (Dyakowska 1956; Rühle 1968; Krupiński and Żarski 2004; Krupiński *et al.* 2004; Żarski *et al.* 2005), Krępa (Jesionkiewicz 1982), Poznań (Winter 1991), Gózd and Adamów (Żarski 2008, 2009).

Of crucial significance for the Middle Pleistocene palaeogeographic reconstructions are studies focused on the Mazovian Interglacial sediments from the border areas with Belarus and Ukraine, as well as those devoted to the extent of the Odranian Glaciation and the Quaternary stratigraphy in the study area (Lindner *et al.* 1990, 1991, 2004a, b, 2006, 2007; Marks and Pavlowskaya 2006; Marks and Karabanow 2017; Marks *et al.* 2018; Marks 2023a,b; Pochocka-Szwarc and Żarski 2023; Żarski *et al.* 2023). Authors of the particular sheets of the Detailed Geological Map of Poland at the scale of 1:50 000 have greatly contributed to the geological recognition of sites with lake deposits of the Mazovian Interglacial in the study area (e.g., Albrycht *et al.* 1995, 1997; Brzezina 2000a, b; Albrycht 2001a, b, 2004, 2005; Małek 2004a, b; Wodyk 2004a, b; Nitychoruk and Gałązka 2006a, b, 2007, 2008; Żarski 2007a, b, 2008, 2009, 2012a, b; Małek and Buczek 2008, 2009). These mapping surveys included palaeobotanic and geological analyses of 39 sites with fossil lake deposits of the Mazovian Interglacial (Żarski *et al.* 2009a).

The Mazovian Interglacial corresponds to MIS 11c (Nitychoruk *et al.* 2005; Rohling *et al.* 2010; Cohen and Gibbard 2011, 2019), the Holsteinian Interglacial in the stratigraphic scheme for Western Europe, the Aleksandrian in the scheme for Belarus (Velichkevich *et al.* 2001), and the Likhwynian in the scheme for Ukraine (Lindner *et al.* 2007) (Table 2).

The Mazovian Interglacial is located in a climatostratigraphic position between the Sanian 2 (Elsterian, MIS 12) and the Liviecian (Fuhne, MIS 11b–MIS 10) glaciations (Ber *et al.* 2007; Lindner and Marks 2012; Hrynowiecka *et al.* 2019; Table 2).

Beside the Liviecian Glaciation (Fuhne, MIS 11b–MIS 10), the Saalian complex (Mid-Polish Glaciation, Odranian Glaciation *s.l.*) also includes the Krznanian Glaciation (Drenthe, MIS 8; Lindner and Marks 2012), during these intervals, however, south-eastern Poland was probably not covered by the Scandinavian ice sheet (Hughes *et al.* 2020). Therefore, post-glacial lakes which in later interglacials would become places of lacustrine and bog accumulation were not formed in the area. This hypothesis is confirmed by geological and palynologic studies, because lacustrine sediments documenting the climate warming during MIS 7 and MIS 9 with a record of the vegetation succession documenting these climatostratigraphic units have so far not been recognized in Poland.

Climatic changes between MIS 11 and MIS 6 are preserved in loess successions, in which interglacial intervals are represented by well-developed paleosols (Lindner *et al.* 2004a, b; Marks et al. 2018; Bogucki and Łanczont 2018; Valde-Nowak and Łanczont 2021).

A paleosol correlated with MIS 7 was also documented in glaciofluvial sands within the Łuków Plain in the Wólka Zagórna site (Terpiłowski *et al.* 2021). This is, however, the only site with such documentation.

## GEOLOGICAL SETTING

The study area with sites recording the Mazovian Interglacial is situated in the southern part of the Łuków Plain which is part of the Southern Podlasie Lowland (Richling 2021; Text-fig. 2). It extends between the Vistula valley in the west and the Bug valley in the east. The southern boundary of the Southern Podlasie Lowland is the margin of the Lublin Upland and the Krzna valley flowing to the Bug valley (Text-fig. 2). The main morphological features of the southern part of the Łuków Plain developed during the Sanian 2 Glaciation (Elsterian, MIS 12). They are usually represented by denuded and flat post-glacial plateaus with numerous drainless basins. Their surface is elevated at 145−165 m a.s.l. (Pochocka-Szwarc and Żarski 2023).

To the south, the Łuków Plain bounds with the Żelechów Heights, whose surface is elevated at 175−185 m a.s.l., i.e., about 20 m higher than the Łuków Plain. The plateau surface gradually decreases from the west to the east. From the north, the Łuków Plain bounds with the Siedlce Heights, where the tops of end moraines reach 190 m a.s.l., and from the east it bounds with the Łomazy Depression and the Parczew-Kodeń Heights, whose surface reaches about 150−155 m a.s.l. (Text-fig. 2).

### Wólka Domaszewska

The site is located about 1 km from Przytulin and 250 m from Kolonia Bystrzycka (Text-figs 2, 3A, 4A). It is situated in a small melt-out basin on a post-glacial plateau composed of glacial tills from the Sanian 2 Glaciation (Elsterian; Text-fig. 5A). The surface of the drainless basin in Wólka Domaszewska lies at about 164 m a.s.l., i.e., about 0.5–1 m lower than the surface of the surrounding post-glacial plateau. The longer N-S axis of the basin has 103 m and the shorter axis has 33 m.

### Kolonia Bystrzycka

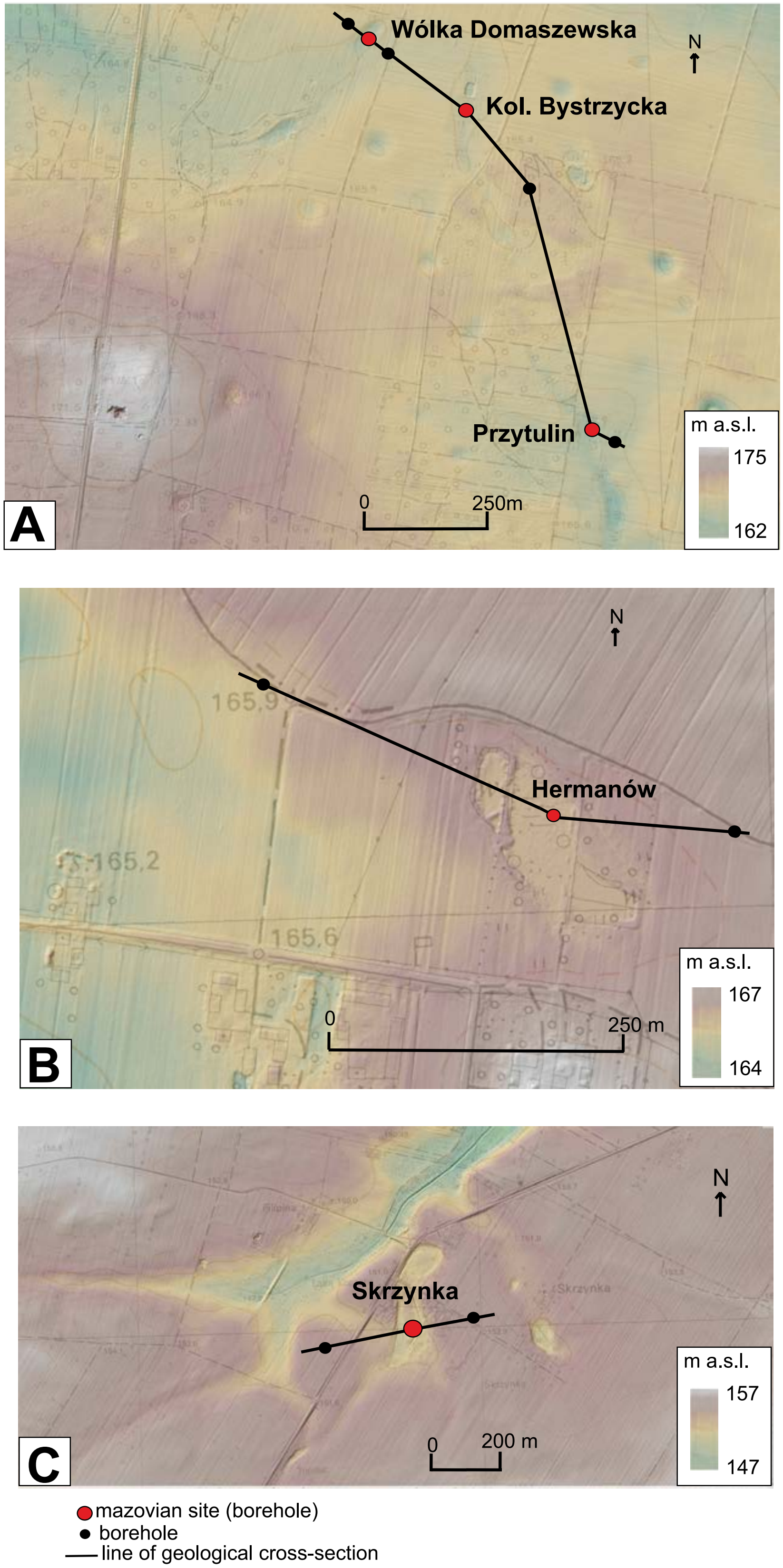
The site is located about 750 m to the north-west of Przytulin (Text-figs 2, 3A, 4B), on the surface of a post-glacial plateau built of glacial tills from the Sanian 2 Glaciation (Elsterian), i.e., the same as in Przytulin and Wólka Domaszewska (Text-fig. 5A). The N-S-oriented drainless basin in Kolonia Bystrzycka is 250 m long and about 30 m wide. It is located at about 164.5 m a.s.l., i.e., about 0.5 m below the plateau surface. In the central part of the depression occurs a lake 20 × 12 m in size, in the wall of which are exposed lake deposits of the Mazovian Interglacial.

### Przytulin

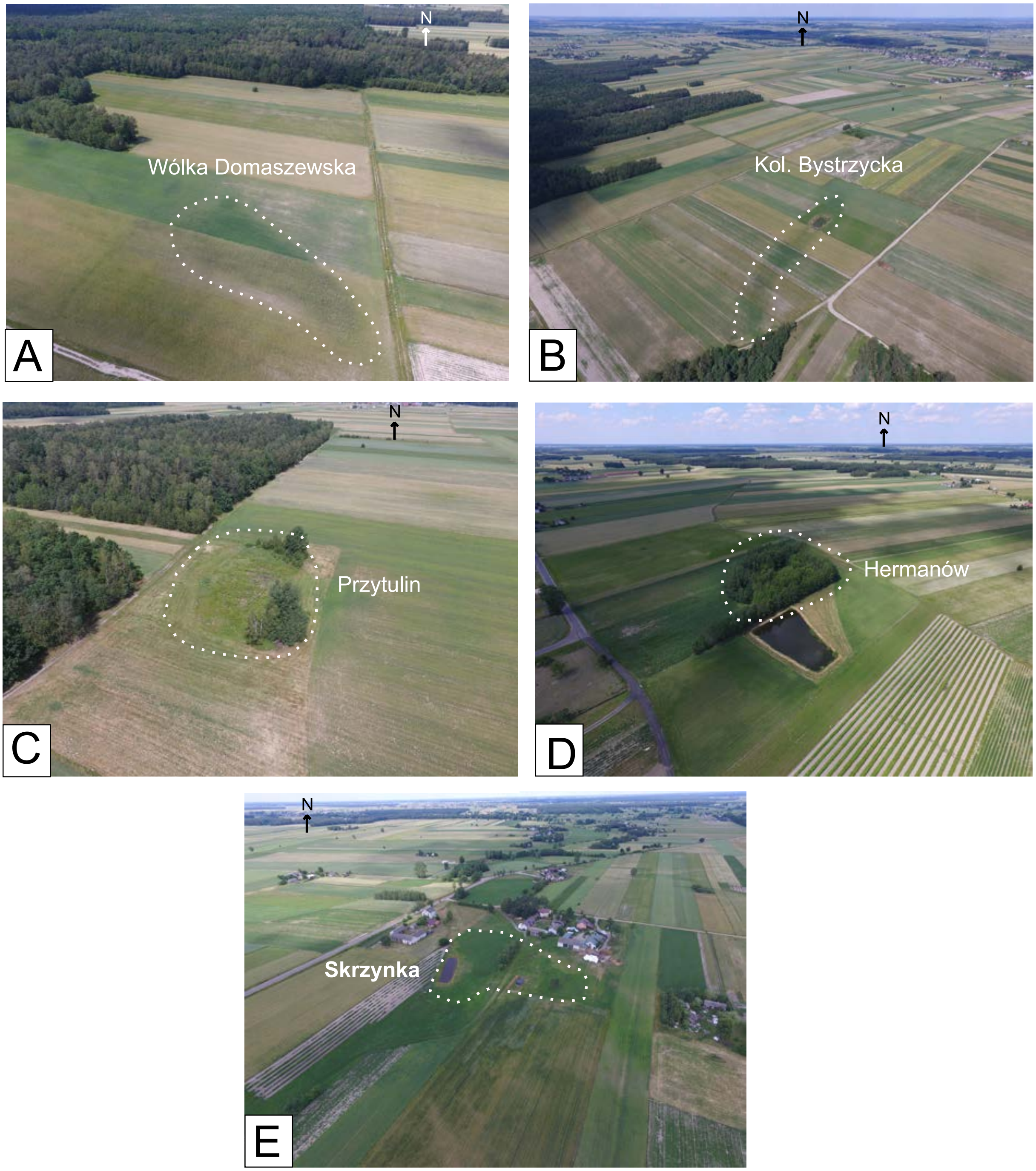
The site is located in the Łuków Plain between Bystrzyca and Mała Bystrzyca, 12 km to the south of Łuków (Text-fig. 2, 3A, 4C). It is situated on a post-glacial plateau in a small depression. The surface lies at about 165 m a.s.l., while the depression lies at about 164 m a.s.l. The depression is carved in glacial tills of the Sanian 2 Glaciation (Elsterian; Text-fig. 5A).

### Hermanów

The site is located about 2 km to the south-east of Przytulin (Text-fig. 2). It is situated on a post-glacial plateau composed of glacial tills of the Sanian 2 Glaciation (Elsterian, MIS 12) and their sandy-silty eluvia. The thickness of glacial tills is from several to




Text-fig. 3. Location of geological cross-sections: A – Wólka Domaszewska-Przytulin, B – Hermanów, C – Skrzynka.

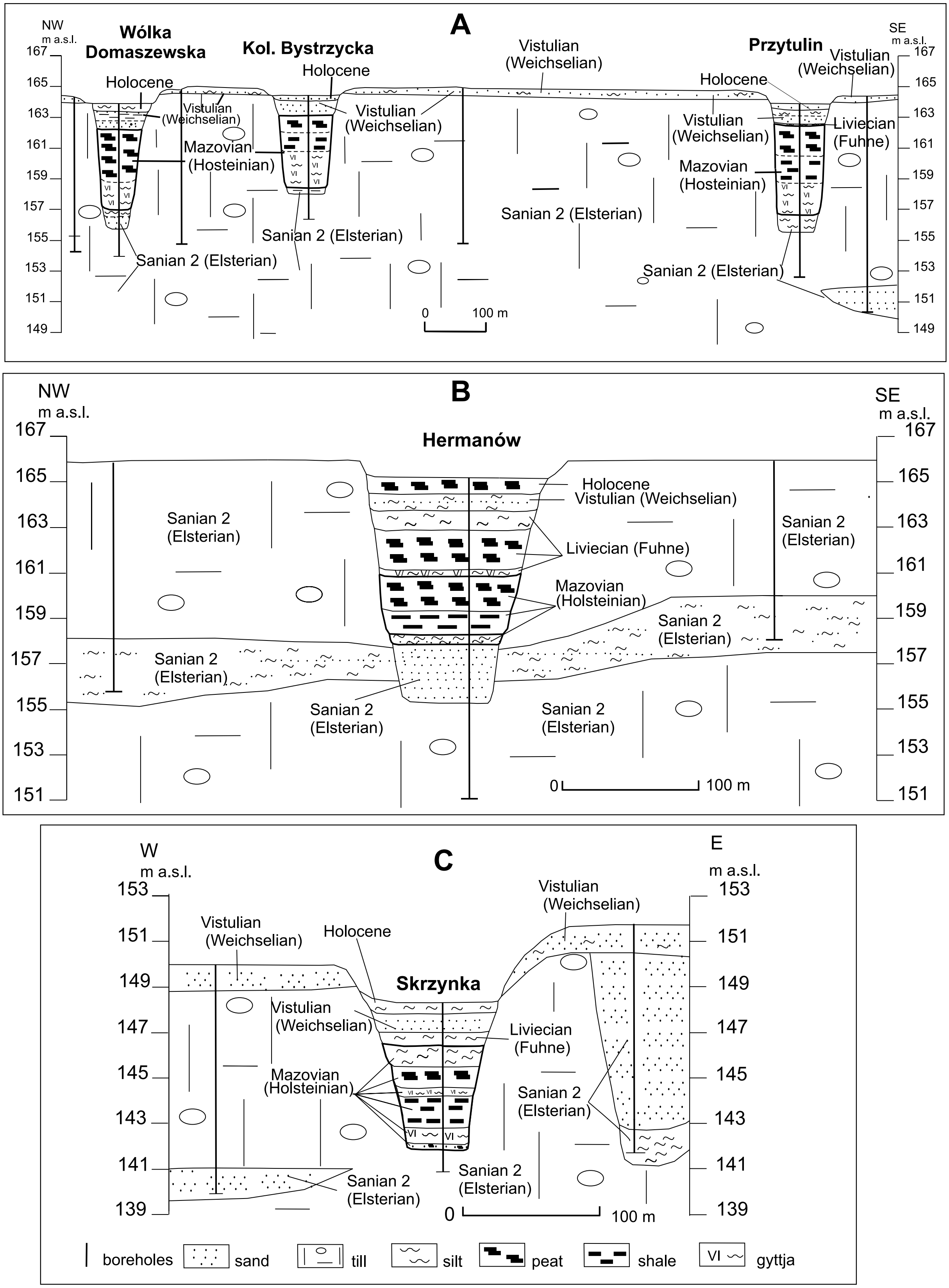



Text-fig. 4. Aerial photographs of the studied sites: A – Wólka Domaszewska, B – Kol. Bystrzycka, C – Przytulin, D – Hermanów, E – Skrzynka. All photographs by M. Żarski.

over a dozen metres (Text-fig. 5B). The site is located in a modern drainless basin, whose longer axis (meridional) reaches about 190 m and the shorter (parallel) – about 90 m (Text-figs 3B and 4D). The surface lies at about 165 m a.s.l.

**Skrzynka**

The site is located about 12 km to the southeast of Hermanów and about 5 km to the north of Kock (Text-figs 2, 3C and 4E). It is situated in a small drain-




Text-fig. 5. Geological cross-section: A –Wólka Domaszewska-Przytulin, B – Hermanów, C – Skrzynka.

less basin, occurring on the surface of a post-glacial plateau. The longer axis of this basin (meridional) is about 200 m, and the shorter (parallel) is140 m. The surface of the basin lies at about 149 m a.s.l. The surface of the plateau is built of glacial tills of the Sanian 2 Glaciation (Elsterian; Żarski 2008, 2009) and their weathering covers (Text-fig. 5C).

Several WH and geoprobe drillings were made on the site in 2005, 2006 and 2012 (Żarski and Krupiński 2005; Żarski 2008, 2009; Żarski *et al.* 2009a). The first palynologic expertise from the WH probe was made by Krupiński (2004c). In 2013, two rotary drillings were made, resulting in successions with intact core structure SKI and SKII. The SKII succession was subject to palynologic analysis (Górecki *et al.* 2022).

## METHODOLOGY

### Drillings

The drillings from which material for palaeobotanical analysis was collected have been made in the frame of the mapping surveys for the Adamów sheet of the Detailed Geological Map of Poland at the scale of 1:50 000 (Żarski 2008, 2009), and the research project "Palaeoclimate and palaeoenvironment changes in the Mazovian Interglacial (Holstenian) in E Poland based on multiproxy palaeobotanic, sedimentological and isotope analyses". Drillings were made in 2004 using a hydraulic drill WH with a spiral auger, on average to the depth of 10 m. In 2005, two fully cored drillings using the Power Probe hammer drill were made in Przytulin and Hermanów to depths of 8 and 8.4 m, respectively.

Samples for petrographic and lithological studies of the mineral sediments were collected from the WH and manual Edelman augers (Żarski 2009). In 2012, surveys in Wólka Domaszewska, Kolonia Bystrzycka, and Hermanów included fully cored geoprobe drillings in the analysed sediments. Samples collected from lacustrine and bog sediments were subject to palynologic analyses; the obtained results are presented herein. In 2013, two rotary drillings were made in Skrzynka; the obtained cores had an intact structure.

### Palaeobotanical analysis

The procedure of sampling for palynological analysis was identical for all analysed successions. 1 $cm^3$ samples were collected from peat and gyttja, while 3 $cm^3$ samples were taken from mineral deposits (tills, silts, sands) due to the expected low frequencies of pollen grains. Most profiles were studied with a standard resolution of 10 cm; in the case of Skrzynka and Wólka Domaszewska part of the profile corresponding to the climate optimum was analysed with a resolution of 2 and 1 cm, respectively (Table 3). The only exception is the Przytulin profile, where depending on the type of sediment the resolution was from 0.5 cm (organic deposits) to 70 cm (mineral deposits). All samples are stored in the Polish Geological Institute-National Research Institute.

Each sample was subject to acetolysis according to Erdtmann (1960) and modified using HF (Berglund and Ralska-Jasiewiczowa 1986). Before laboratory treatment, one pill of the *Lycopodium* index was added to each sample to determine the concentration of palynomorphs (Stockmar 1971). Palynological samples were counted under a light microscope supported by using POLPAL software (Nalepka and Walanus 2003). In most samples, the counting was up to 500 pollen grains of trees and herbaceous plants (excluding aquatic and mire plants).

| Profiles | Depth [m] | Sampling resolution [cm] | Number of analysed samples |
|---|---|---|---|
| Wólka Domaszewska | 5.56 | 1–10 | 117 |
| Kolonia Bystrzycka | 2.75 | 10 | 29 |
| Przytulin | 7.45 | 0.5–70 | 41 |
| Hermanów | 5.50 | 10 | 56 |
| Skrzynka | 4.30 | 2/10 | 161 |

Table 3. List of samples collected for palynologic analysis.

In the case of low pollen concentrations (glacial deposits) the counting was restricted to 100–300 pollen grains. Percentage counts are constructed on the basic sum, which includes tree and shrub pollen (AP), herbaceous plants and dwarf plants (NAP). The diagrams were prepared with the application of R Studio software (R Studio Team 2020) using the riojaPlot package (Juggins 2022).

### Lithological-petrographic methods

The petrographic composition of gravels washed out from glacial tills was analysed in the 0.5–1 cm fraction following the methodology of Krygowski (1956, 1967), Rzechowski (1977), Kenig (1998), and Lisicki (2003). Indexes O/K–K/W–A/B were used for the lithostratigraphic comparison of glacial till horizons (where: O/K – ratio of the content of Scandinavian sedimentary rocks to the Scandinavian crystalline rocks together with quartz, K/W – ratio of Scandinavian crystalline rocks together with quartz to Scandinavian limestones and dolomites, and A/B – ratio of Scandinavian rocks susceptible to destruction to rocks resistant to destruction). Studies of the petrographic composition of glacial tills are important for lithostratigraphic correlation (Lisicki 2003). The analysis of the petrographic composition was performed for Przytulin, Wólka Domaszewska, and Hermanów (Żarski *et al.* 2009b, c; Hrynowiecka *et al.* 2019).

### Analysis of grain-size composition

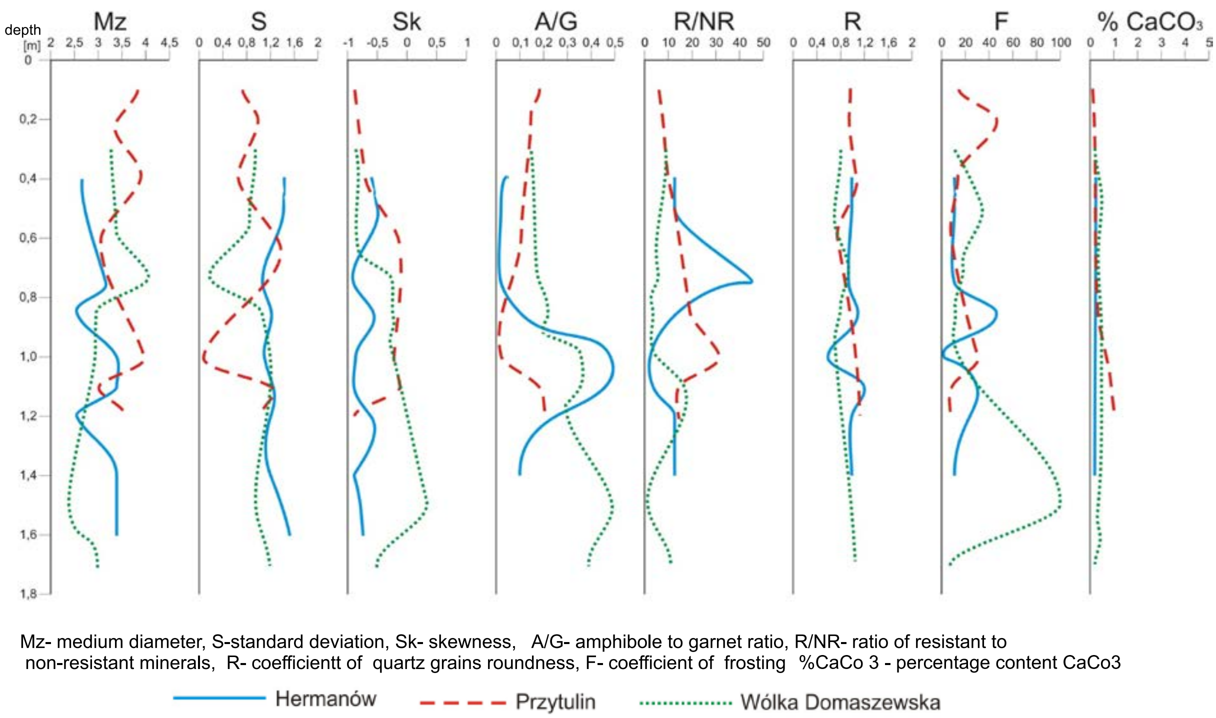
The grain-size composition using the sieve method (Racinowski 1973) was tested for sand-silt deposits covering the lake series in Hermanów, Przytulin, and Wólka Domaszewska. A set of sieves with mesh sizes 0.06–2.5 mm was used in the analysis. Statistic parameters of the grain-size distribution were calculated based on the formulae by Folk and Ward (1957), supplemented with rounding (R) and matting coefficients of quartz grains. Analysis of the grain size composition is aimed to characterize the basic lithological and genetic features. The analyses were made in sediments covering the interglacial deposits with a resolution of 10 cm, in places also 20 cm (Text-fig. 6).

### Heavy mineral analysis

Heavy mineral (density exceeding 3 g/cm$^3$) analysis was made for the 0.25−0.1 mm fraction. The heavy fraction was extracted from 10 g samples using bromoform, according to the methodology of Mycielska-Dowgiałło and Rutkowski (1995), Racinowski (1995), Barczuk and Nejbert (2007), and Marcinkowski and Mycielska-Dowgiałło (2013). Transparent and opaque heavy minerals were distinguished. Transparent minerals include those that are resistant to destruction, e.g., zircon, tourmaline, sillimanite, staurolite, garnet, as well as susceptible to destruction, e.g., amphiboles, pyrite, biotite, and olivine. Mutual relationships between these mineral groups have high significance in tracing the sediment origin. Opaque minerals include most oxides and sulphides of iron, sulphur, chromium, manganese, tungsten, and native and precious metals. Analysis of the composition of heavy minerals was performed for Przytulin, Wólka Domaszewska, and Hermanów (Żarski *et al.* 2009b, c).

### Rounding and matting of quartz grains

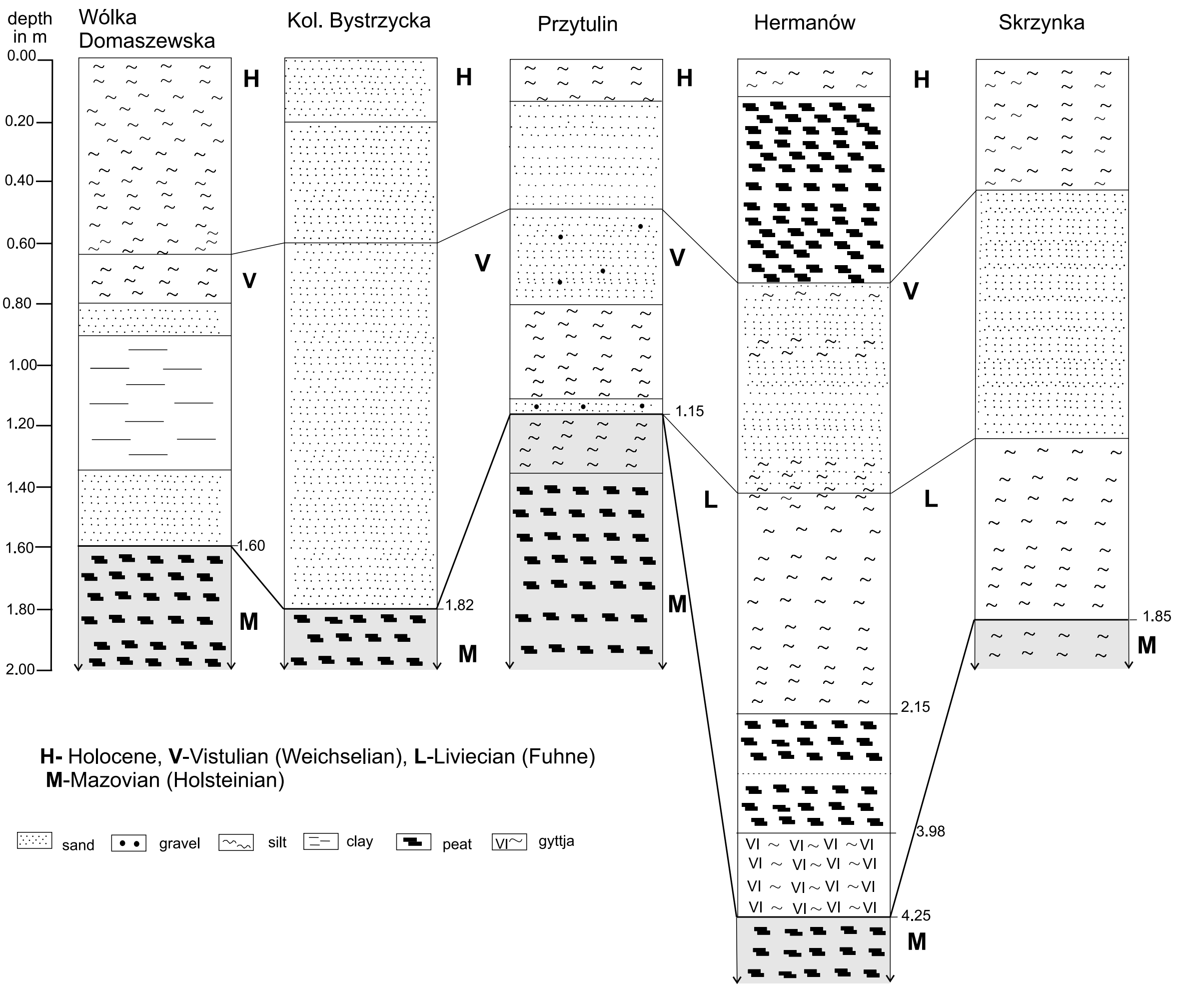
Analysis of the rounding, matting and surface of quartz grains is usually performed for the 0.5–1.0 mm fraction, following the methodology of Cailleux (1942, 1961), Morawski (1955), Krygowski




Text-fig. 6. Results of lithological analyses of sediments covering lacustrine deposits of the Mazovian Interglacial and early Liviecian (based on Żarski *et al.* 2009b).

| Name of site (coordinates) | Depth | Lithology | Origin | Stratigraphy | MIS |
|---|---|---|---|---|---|
| Wólka Domaszewska (51°49’42.3”N 22°20’6.6”E) | 0.0–0.65 | Silt, black-brown | li | Holocene | 1 |
| | 0.65–0.80<br>0.80–0.90<br>0.90–1.35<br>1.35–1.60 | Silt, light grey<br>Poorly sorted sand, grey<br>Clay, grey-rusty<br>Medium and fine-grained sand with rare gravels (Ø 0.25 cm), grey | li<br>d<br>li<br>d | Vistulian | 2 |
| | 1.60–2.10 | Peaty silt with clay, dark brown | bio | Early Liviecian | 11b |
| | 2.10–4.75<br>4.75–6.75 | Peat, brown-black<br>Gyttja, olive-green | bio<br>li | Mazovian | 11c |
| | 6.90–7.20 | Fine-grained sand with plant macroremains, grey | li | Sanian 2 | 12 |
| Kolonia Bystrzycka (51°49’33.6”N 22°20’17.1”E) | 0.0–0.20<br>0.20–0.60 | Humus sand, black<br>Fine-grained sand, beige | d-li<br>d | Holocene | 1 |
| | 0.60–1.82 | Fine-grained sand, grey | d | Vistulian | 2 |
| | 1.82–2.15<br>2.15–2.40<br>2.40–2.90<br>2.90–4.35 | Peat, brown-black<br>Peat shale, brown-black<br>Peat, brown-black<br>Gyttja, olive-green | bio<br>bio<br>bio<br>li | Mazovian | 11c |
| | 4.35–4.40<br>4.40–5.10<br>5.10–6.20 | Gyttja, olive-green<br>Fine-grained sand with intercalations of silt and plant macroremains, grey<br>Fine-grained sand, grey | li<br>li<br>gf | Sanian 2 | 12 |
| Przytulin (51°49’14.6”N 22°20’28.6”E) | 0.0–0.15<br>0.15–0.50 | Humus silt, dark grey<br>Fine-grained and silty sand, brown | li<br>d | Holocene | 1 |
| | 0.50–0.80<br>0.80–1.10<br>1.10–1.15 | Fine-grained sand with single gravels, grey<br>Silt, light brown<br>Fine-grained sand with single gravels, grey | d<br>li<br>d | Vistulian | 2 |
| | 1.15–1.25<br>1.25–1.35<br>1.50–3.20<br>3.20–4.70<br>4.70–5.20<br>5.20–7.35 | Silt, dark grey-brown<br>Silt, dark grey-brown<br>Peat, brown<br>Peat shale, black<br>Gyttja, dark grey<br>Gyttja, olive-green | li<br>li<br>bio<br>bio<br>li<br>li | Mazovian | 11c |
| | 7.35–8.7<br>8.7–11.7 | Clay silt, grey<br>Glacial till | li-g<br>g | Sanian 2 | 12 |
| Hermanów (51°48’19.2”N 22°22’9.8” E) | 0.0–0.75 | Peat, brown-black | li | Holocene | 1 |
| | 0.75–1.42 | Fine-grained sand with silt intercalations, brown | d-li | Vistulian | 2 |
| | 1.42–2.15 | Laminated silt | li | Liviecian | 10 |
| | 2.15–3.98<br>3.98–4.25 | Peat, brown-black<br>Gyttja, olive-green | bio<br>li | Early Liviecian | 11a<br>11b |
| | 4.25–5.72<br>5.72–6.70<br>6.70–6.98<br>6.98–7.32 | Peat, brown-black<br>Peat shales<br>Silt, dark grey<br>Sand | bio<br>bio<br>li<br>d-li | Mazovian | 11c |
| | 7.32–7.75 | Fine-grained sand | gf | Sanian 2 | 12 |
| Skrzynka (51°43’21.5”N 22°26’21.4”E) | 0.0–0.45 | Silt, brown | li | Holocene | 1 |
| | 0.45–1.25 | Fine-grained sand, brown | d | Vistulian | 2 |
| | 1.25–1.85 | Clay silt, grey-olive-green | li | Early Liviecian | 11b |
| | 1.85–2.10<br>2.10–2.63<br>2.63–3.50<br>3.50–3.82<br>3.82–5.40<br>5.40–5.92<br>5.92–6.15 | Silt, grey-olive-green<br>Silt, grey-black<br>Peat, brown-black<br>Gyttja, olive-green<br>Gyttija shales, olive-green<br>Peat gyttja, brown-black<br>Humus sand with peat intercalations | li<br>li<br>bio<br>li<br>li<br>li<br>bio-d | Mazovian | 11c |
| | 6.15–7.45 | Glacial till, grey | g | Sanian 2 | 12 |

Table 4. Lithological and stratigraphic characteristics of the analysed successions. Abbreviations: li – limnic; bio – biogenic; d – deluvial; gf – glaciofluvial; g – glacial.




Text-fig. 7. Stratigraphic correlation of sediments covering lacustrine formations of the Mazovian Interglacial and early Liviecian (based on Żarski *et al.* 2009b, modified).

(1964), and Mycielska-Dowgiałło (1995). Of high significance are three-grain groups: non-rounded (NU), shining rounded (EL) and round matted (RM), as well as transitional groups.

### Analysis of the $CaCO_3$ content

The analysis was performed on samples in the <0.1 mm fraction. The analysed sediment was floated in distilled water on a sieve with a 0.1 mm mesh size. Next, the $CaCO_3$ content was determined using the volumetric method with application of the Scheibler apparatus (Myślińska 2016). This apparatus registers the volume of carbon dioxide emitted from carbonate decomposition. The volume is calculated using the formula for the percentage content of calcium carbonate in the sediment.

## RESULTS

### Lithological analysis

The interval with the Mazovian Interglacial (MIS 11c) in Wólka Domaszowska reaches a thickness of 5.15 m. It begins with gyttja, followed by peat and silts (Table 4). The gyttja is underlain by lacustrine sands of the late Sanian 2 Glaciation (Elsterian, MIS 12; Table 4) and glaciofluvial sands of the Sanian 2 Glaciation occurring below; the drilling terminated in the glacial till of the Sanian 2 Glaciation. The topmost part of the Mazovian Interglacial is overlain by 0.95 m of diluvial sands and 0.95 m of lake silts and clays correlated with the Vistulian Glaciation (MIS 2), while Holocene (MIS 1) lake silts, 0.65 m thick, occur above (Text-fig. 7).

In Kolonia Bystrzycka, lake deposits of the Mazovian Interglacial (MIS 11c) reach 2.53 m, and begin with lake gyttja overlain by peat shales and peats (Text-fig. 5A, Table 4).The Mazovian interval is underlain by lake gyttja and lacustrine sands of the late Sanian 2 Glaciation, and glaciofluvial sands lying on glacial tills of the Sanian 2 Glaciation (Elsterian, MIS 12; Text-fig. 5A). The Mazovian series is covered by a Vistulian (MIS 2) series of diluvial sands, 1.22 m thick, overlain by Holocene sands (0.60 m thick, MIS 1, Text-fig. 7).

The thickness of the Mazovian lake series in Przytulin reaches 6.2 m and comprises lake gyttja, followed by peat and lake silts. The lacustrine series is underlain by ice-dammed silts lying on the glacial till of the Sanian 2 Glaciation (Elsterian, MIS 12; Table 4). The lacustrine series is overlain by a 0.65 m series of sands and silts correlated with the Vistulian Glaciation (MIS 2), and covered by a 50 cm bed of Holocene sands and silts (MIS 1; Table 4 and Text-fig. 7).

In Hermanów, the interval corresponding to the Mazovian Interglacial (MIS 11c) reaches 3.07 m and begins with lake sands and silts, overlain by peat shales and peat (Table 4, Text-fig. 5B; Hrynowiecka *et al.* 2019). Below occur glaciofluvial sands located on glacial till of the Sanian 2 Glaciation (Elsterian, MIS 12; Text-fig. 5). The Mazovian series is overlain by a lake series with gyttja, peats and silts, 2.83 m thick, from the early Liviecian Glaciation (MIS 11b–a; Hrynowiecka *et al.* 2019), overlain by diluvial sands (0.67 m) of the Vistulian Glaciation (MIS 5d–2), and covered by 0.75 m of Holocene peat (Table 4, Text-fig. 7; Hrynowiecka *et al.* 2019).

In Skrzynka, the Mazovian Interglacial (MIS 11c) series is 4.3 m thick and begins with sands with peat intercalations, passing into gyttja, overlain by lake peat and silts (Górecki *et al.* 2022). Below the lacustrine series occur glacial tills of the Sanian 2 Glaciation (Elsterian, MIS 12; Table 4, Text-fig. 5C). The series is covered by lacustrine silts of the Liviecian Glaciation MIS 10 (0.6 m thick), overlain by diluvial sands correlated with the Vistulian Glaciation (MIS 2), and Holocene Lake silts (MIS 1; Table 4; Text-fig. 7).

## Petrographic analysis

Petrographic analysis of gravels in the 0.5–1 cm fraction was made for WH profiles from Przytulin, Hermanów, and Wólka Domaszewska in the depth interval 1.3–10 m. Samples were collected from the following intervals: 2–4, 4–6 and 8–10 m (Table 5). An additional sample was collected in Przytulin from a depth interval of 1.3–2 m.

To the depth of 8.0 m occur strongly weathered gravels with a petrographic composition pointing to intense weathering processes that the topmost parts of the till were subject to. In Przytulin to the depth of 8.0 m occur exclusively gravels composed of rocks very resistant to weathering (Table 5). These include mainly Scandinavian crystalline rocks, very compact quartzitic sandstones, subject to strong diagenesis, with a siliceous matrix and smooth transitions to quartzites, and flints (representing local rocks). The weathering process is documented by strongly weathered gravels. Their petrographic identification is difficult. From the depth of 8.0 m the gravels from glacial tills contain also Scandinavian limestones and dolomites in amounts comparable with the number of crystalline rocks. The weathering of glacial till and gravel at this depth is insignificant. The sum of sedimentary rocks equals the sum of crystalline rocks. Only the petrographic coefficients obtained from 8.0–10.0 m can be used for determining the glacial till lithotype, and at the same time for determining the age of the Sanian 2 Glaciation (Elsterian, MIS 12; Żarski *et al.* 2009b).

## Grain-size analysis

The analysed fraction is dominated by fine and medium-grained sands, moderately, moderately well to poorly sorted. The most diverse proportions of the sand and silt fractions occur in Przytulin. The site is characterised by sandy silts and silty sands with diverse contents of the particular fractions. In extreme

| Depth [m] | Scandinavian rocks | | | | | Local rocks | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Cr | Lp | Dp | Sp | Qp | L | S | F | M | I |
| Przytulin | | | | | | | | | | |
| 1.3–2.0 | 42 | – | – | 22 | 15 | – | – | 4 | – | 8 |
| 2.0–4.0 | 54 | – | – | 15 | 25 | – | – | 20 | – | 14 |
| 4.0–6.0 | 43 | – | – | 13 | 14 | – | – | 2 | – | 4 |
| 8.0–10.0 | 53 | 41 | 16 | 9 | 10 | 5 | 1 | 1 | – | – |
| Hermanów | | | | | | | | | | |
| 2.0–4.0 | 37 | – | 1 | 14 | 10 | – | – | | – | 7 |
| 4.0–6.0 | 20 | 2 | – | 15 | 5 | – | – | 2 | – | 4 |
| 8.0–10.0 | 28 | 14 | 3 | 4 | 4 | 1 | 2 | 2 | 3 | – |
| Wólka Domaszewska | | | | | | | | | | |
| 2.0–4.0 | 36 | 2 | 1 | 12 | 11 | 2 | – | 4 | – | 6 |
| 4.0–6.0 | 42 | 2 | – | 7 | 5 | 1 | 1 | 2 | – | 3 |
| 8.0–10.0 | 32 | 27 | 6 | 4 | 4 | – | 2 | | 3 | – |

Table 5. Petrographic composition of gravels in Przytulin, Hermanów and Wólka Domaszewska (Żarski *et al.* 2009b; Hrynowiecka *et al.* 2019). Abbreviations: Cr – crystalline rocks; Lp – Palaeozoic limestones; Dp – Palaeozoic dolomites; Sp – Palaeozoic sandstones; Qp – quartz; L – limestones; S – sandstones; F – flints; M – mudstones; I – weathered crystalline rocks.

cases in Przytulin the proportions reach 92.94% of the silt fraction and 7.06% of the sand fraction. In Wólka Domaszewska, the content of the sand fraction is 87.93% and of the silt fraction – 12.07% (Text-fig. 6). The domination of one or two fractions in a sample point to good sorting of the sediment.

In the remaining samples collected from the analysed successions the proportions of sand and silt fractions are variable, both horizontally as well as in section. Variable quantities of particular fractions reflect the change in transportation dynamics preceding the sedimentation. Studies of the quartz grain surfaces have shown that most of them (70−80%) have a matted surface and are indirectly rounded (Text-fig. 6). It may be assumed that the studied sediments are the effect of weathering of glacial deposits, which were sorted in water with a diverse transport energy, and subject to later aeolization processes (Text-fig. 6).

## Heavy minerals

Studies on the presence of heavy minerals were made on the same samples that were subject to grain-size analysis. The heavy minerals include mainly minerals resistant to mechanical destruction, which were subject to selection, and are medium and well-rounded (round, oval, ellipsoidal and rounded sides). The selection of heavy minerals is caused by specific conditions of the sedimentary environment. At first they were transported in water and then were subject to aeolization processes. The analysed samples are

| Marine Isotope Stage | Hermanów | Ossówka | Nowiny Żukowskie | Wólka Domaszewska | Skrzynka | Germany | Przytulin | Kolonia Bystrzycka 2 | Mazovian Interglacial palynostratigraphy (POL) |
|---|---|---|---|---|---|---|---|---|---|
| MIS 11a | HE-21 HE-20 | | | | | | | | |
| MIS 11b | HE-19 | OS-14 | | | | | | | |
| | HE-18 HE-17 | OS-13 | | | | | | | |
| | HE-16 | OS-12 | | | | | | | |
| | | OS-11 | | | | | | | |
| | HE-15 | OS-10 | NŻ-14 | | | | | | |
| | HE-14 | OS-9 | NŻ-13 | WD-11 | | | | | |
| | HE-13 HE-12 | OS-8 | NŻ-12 | WD-10 | SK-14 | | | | |
| MIS 11c | HE-11 | OS-7 | NŻ-11 | WD-9 | SK-13 | XIV | | | *Pinus* |
| | | | NŻ-10 | WD-8 | SK-12 | | PRZ-9 | | BHO |
| | | | NŻ-9 | WD-7 | SK-11 SK-10 | | | | *Pinus* |
| | HE-10 | OS-6 | NŻ-8e | | SK-8 | XIII | PRZ-8 | | *Carpinus–Abies* |
| | HE-9 | | NŻ-8d | | SK-8 | XII | | | |
| | HE-8 | | NŻ-8c | WD-6 | SK-7 | XI | | | YHO |
| | HE-7 | | NŻ-8b | | SK-6 | X | | KB2-6 | *Carpinus–Abies* |
| | HE-6 | | NŻ-8a | | | IX | | | |
| | HE-5 | OS-5 | NŻ-7 | | SK-5 | VIII | PRZ-7 | KB2-5 | OHO |
| | HE-4 | OS-4 | NŻ-6 | WD-5 | SK-4 | VII | PRZ-6 | KB2-4 | *Picea–Alnus–Taxus* |
| | | | NŻ-5 | | | VI | | | |
| | HE-3 | OS-3 | NŻ-4 | WD-4 | SK-3 | V | PRZ-5 | KB2-3 | *Picea–Alnus* |
| | | | NŻ-3 | | SK-2 | IV | PRZ-4 | | |
| | HE-2 | OS-2 | NŻ-2 | WD-3 | SK-1 | III | PRZ-3 | KB2-2 | *Betula–Pinus* |
| | HE-1 | | | WD-2 | | II | PRZ-2 | KB2-1 | *Betula* |
| MIS 12 | | OS-1 | NŻ-1 | WD-1 | | I | PRZ-1 | | Late Sanian 2 Glaciation |

Table 6. Stratigraphic correlation of the studied successions with the records at Ossówka (OS; Nitychoruk *et al.* 2005), Hermanów (HE; Hrynowiecka *et al.* 2019), and Nowiny Żukowskie (NŻ; Hrynowiecka-Czmielewska 2010), the German scheme (Meyer 1974; Koutsodendris *et al.* 2012), and the Mazovian Interglacial scheme in Poland (POL; Krupiński 1995; Janczyk-Kopikowa 1996; Winter 2008). MIS – Marine Isotope Stages after Lisiecki and Raymo (2005) and Hrynowiecka et al. 2019; OHO – Older Holsteinian Oscillation; YHO – Younger Holsteinian Oscillation; BHO – Birch Holsteinian Oscillation.

dominated by minerals that are resistant or very resistant to mechanical destruction, with densities between 3 g/cm$^3$ to slightly over 4 g/cm$^3$ (garnets, tourmaline, zircon, staurolite, topaz, ilmenite, dystene), which in most samples contribute to over 90% of the fraction, whereas minerals susceptible to destruction (amphiboles, pyroxenes) occur in quantities below 10%. Based on the analysed minerals it can be assumed that the sediments were transported in water, and then were subject to aeolization in periglacial conditions, to be finally deposited in a drainless basin.

### Calcium carbonate content

The analysed sand-silt deposits are characterized by a stable, low content of calcium carbonate, and in all samples (Text-fig. 6) reach from a tenth to 1%. This content is typical for sediments transported in water.

### Palynologic analysis

Pollen analysis of the studied profiles has confirmed the Mazovian Interglacial (MIS 11c, Holsteinian) age of the sediments. High contents of NAP in the bottom part of the Wólka Domaszewska (Text-fig. 8) and Przytulin (Text-fig. 10) sections suggest the formation of the basin already at the end of the Sanian 2 Glaciation (MIS 12). At that time climatic conditions that were harsh and unfavourable for a dense vegetation cover prevailed. This generated surface flow and redeposition of mineral deposits in the basins. The area was mainly overgrown by herbaceous plants forming a mosaic of steppe-like plant communities with Poaceae and Amaranthaceae. Trees appeared sporadically.

The sections in Przytulin (Text-fig. 10), Skrzynka (Text-fig. 12), Wólka Domaszewska, and Hermanów (Text-figs 8 and 11) represent a complete or almost complete plant succession characteristic of MIS 11c in eastern Poland (Table 6). It begins with the *Betula* (*–Pinus*) phase, followed by the older part of the climatic optimum – the *Alnus–Picea* phase – and the intra- interglacial cooling known as the Older Holsteinian Oscillation (OHO; Koutsodendris *et al.* 2010).

Sedimentation of biogenic deposits in Kolonia Bystrzycka (Text-fig. 9) ended after the OHO. In the remaining sites the record encompasses also the younger part of the climate optimum – the *Abies–Carpinus* phase and the terminal *Pinus* phase. The vegetation success pattern in all the descibed sites conforms with data from other sites in this part of Europe (Krupiński 1995; Janczyk-Kopikowa 1996; Winter 2008). Elaborate comparisons for Skrzynka and Hermanów are presented in separate publications (Hrynowiecka *et al.* 2019; Górecki *et al.* 2022). Palynologic data from Hermanów and Wólka Domaszewska suggest functioning of the basin during climatic changes of stadial/interstadial rank (Table 6; HE 12-21 LPAZs; WD 10-11 LPAZs), which in the case of Hermanów may be correlated already with the early Liviecian Glaciation (MIS 11b-a; Hrynowiecka *et al.* 2019).

## DISCUSSION

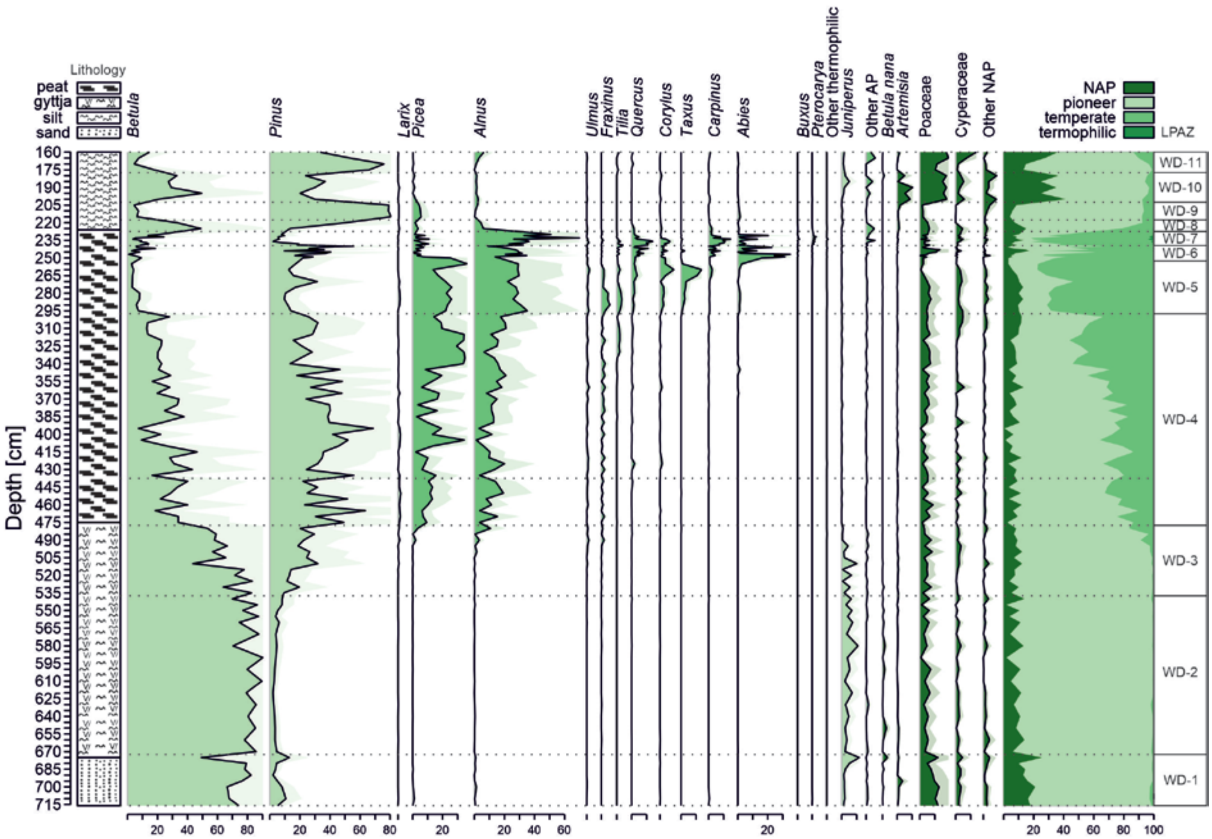
Detailed geological studies including palynological data have allowed us to state that the ice sheet of the Odranian Glaciation did not cover the southern part of the Łuków Plain. The youngest glaciation which covered the study area was the Sanian 2 Glaciation (Elsterian, MIS 12).

The evidence for this assumption is the occurrence of fossil lake deposits with a documented Mazovian Interglacial (Holsteinian, MIS 11c) pollen succession directly below the surface, i.e., in-depth interval 1.3–2.2 m. Fossil lake deposits were not covered by glacial deposits, which is evidence that the area was not covered by the ice sheet of the Odranian Glaciation (MIS 6) (Text-fig. 7).

In most sites, the top of lake deposits of the Mazovian Interglacial or the early Liviecian Glaciation occurs at a depth of about 1.5 m (Table 4, Text-figs 5B, C and 7).

Geological studies indicate that the fossil lake basins are carved in glacial tills of the Sanian 2 Glaciation (Elsterian, MIS 12; Text-fig. 5A–C). The till is moderately weathered and its petrographic composition in the 0.5–1 cm fraction is dominated by gravels of Scandinavian crystalline rocks and sandstones. Only in Przytulin in the depth interval 8–10 m petrographic indices point to a lithotype correlated with the Sanian 2 Glaciation (Elsterian, MIS 12; Lisicki 2003). Similar results were obtained for Domaszki located in the Łuków Plain (Terpiłowski *et al.* 2014), as well as other sites in the southern part of the Southern Podlasie Lowland (Czubla *et al.* 2013, 2019).

The lake deposits infill basins that were formed due to the uneven erosional activity of the Sanian 2 (MIS 12) ice sheet and later, during deglaciation, were infilled with dead ice. Lakes were formed due to favourable local hydrological conditions after the melting of dead ice blocks. The lakes can be referred to as small waterholes, often elongated



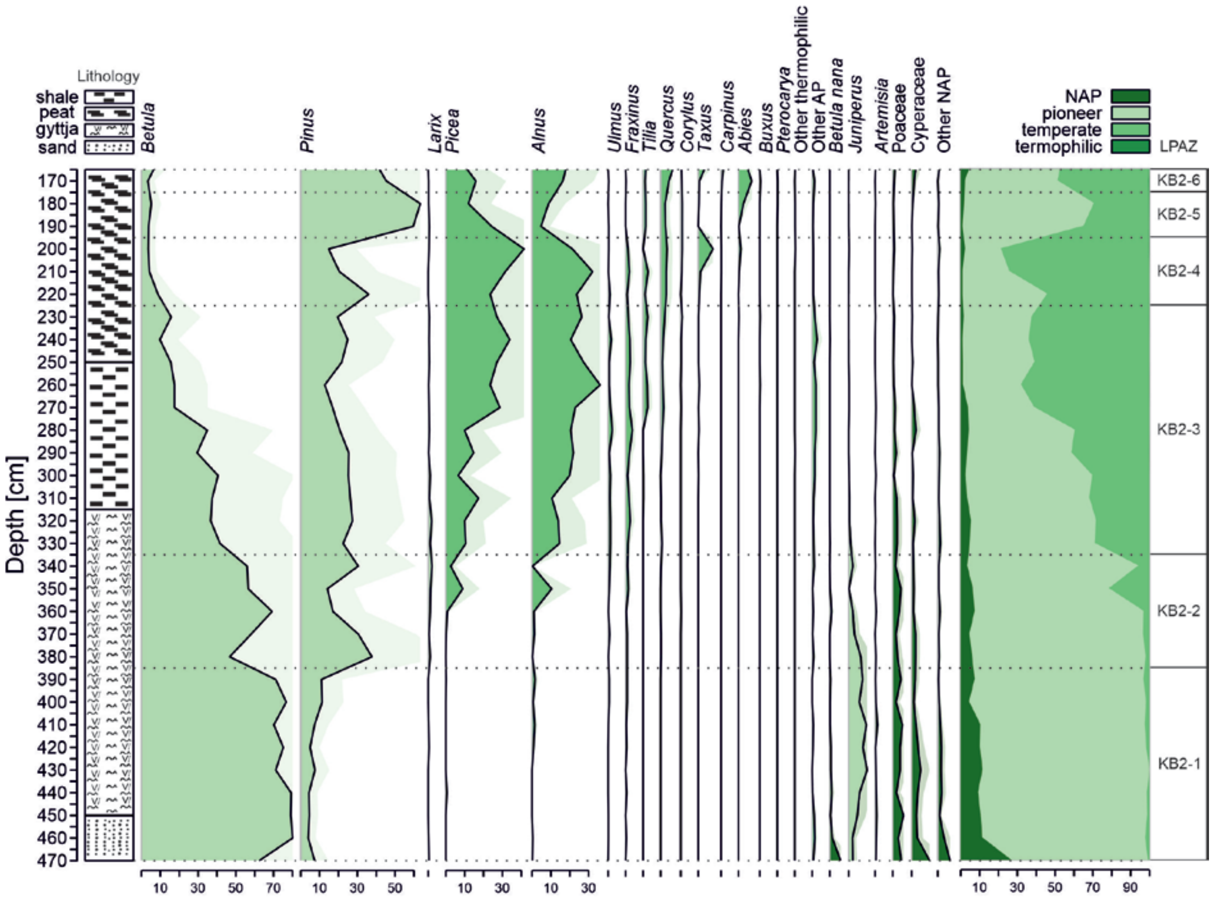
Text-fig. 8. Pollen diagram for Wólka Domaszewska (A. Hrynowiecka and A. Górecki).

in shape. Similar small melt-out lakes occur presently in the young glacial relief of northern Poland (Błaszkiewicz 2005, 2008, 2011), which was covered by the Vistulian Glaciation (Weichselian, MIS 2).

Key arguments in the discussion on the lack of an ice sheet cover in the study area during the Odranian Glaciation (Saalian, MIS 6) are the origin and age of the sediments overlying the lake deposits of the Mazovian Interglacial. In Hermanów and Skrzynka (Text-fig. 7), the lake deposits are overlain by mineral lacustrine deposits representing the early Liviecian Glaciation (MIS 11b–10). They are best developed in Hermanów (Hrynowiecka *et al.* 2019), where lake deposits of the Liviecian Glaciation are covered by a sandy-silty series of diluvial-lake sediments representing the Vistulian Glaciation (MIS 2). In Wólka Domaszewska, Kolonia Bystrzycka, and Przytulin (Text-fig. 7), sediments of the Vistulian occur directly on deposits of the Mazovian Interglacial. Detailed lithological-petrographic studies of the Vistulian were conducted in three sites: Przytulin, Wólka Domaszewska, and Hermanów. The results clearly indicate the presence of sandy-silty sediments that were subject to multiple reworking, which took place in aqueous and eolian settings typical of the periglacial climate.

The source material of these sediments was glacial deposits subject to intense weathering. In general, the sediments infilled depressions on the surface due to washing out, thus their origin can be determined as diluvial and their age can be connected with the Vistulian (MIS 2). Above the diluvial sediments occur Holocene peats (Hermanów), peaty silts (Wólka Domaszewska) or humus sands (Przytulin). The character and origin of these sediments preclude their glacial origin.

Palaeobotanical studies clearly show that the analysed sites contain lake deposits representing the entire Mazovian Interglacial and that these were not destroyed by later erosional processes. The characteristic development of the Mazovian succession of vegetation includes the subsequent colonization of forest communities by tree taxa: *Betula*, *Pinus*, *Alnus* and *Picea*, *Taxus*, *Abies* and *Carpinus*



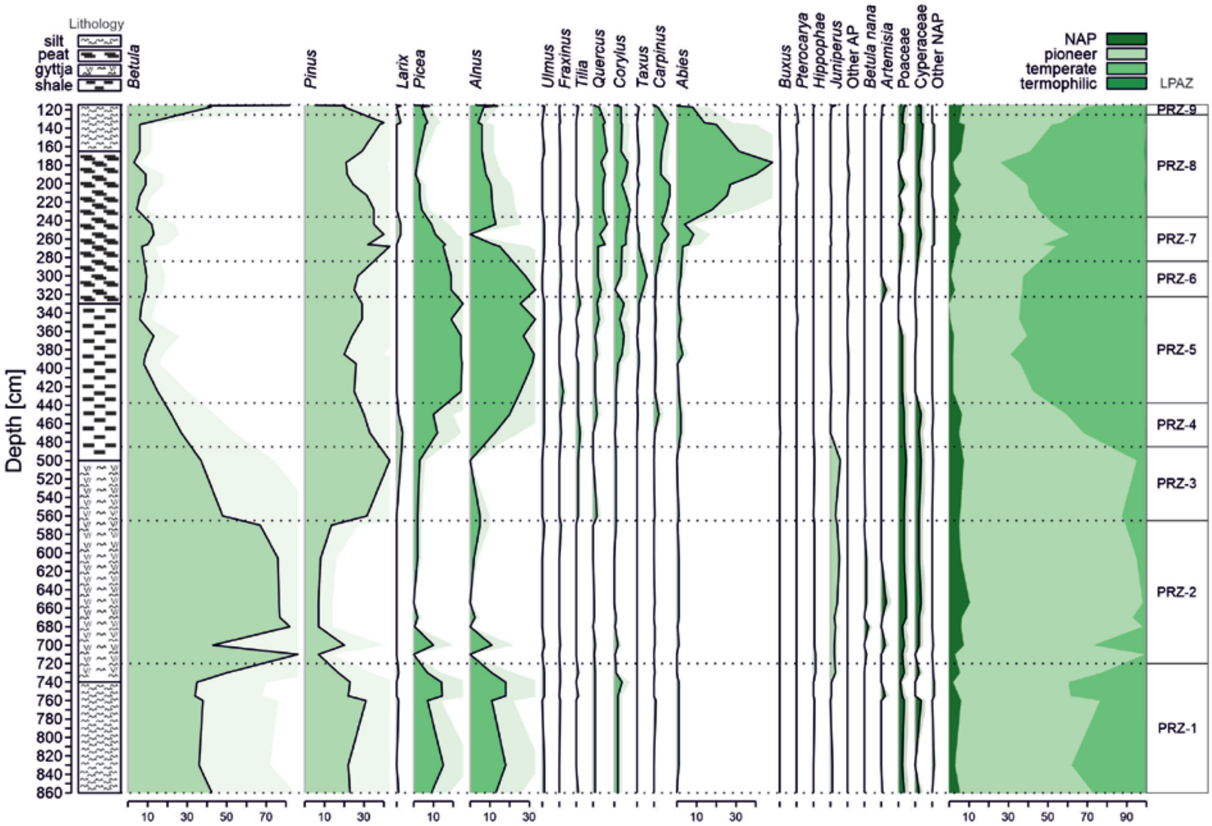
Text-fig. 9. Pollen diagram for Kol. Bystrzycka 2 (A. Górecki).

(Janczyk-Kopikowa 1996; Winter 2008). The last vegetation phase of the interglacial is linked with the presence of boreal forests dominated by *Pinus*. *Taxus* pollen is present also in other interglacials (Pidek 2013; Kupryjanowicz *et al.* 2018), but it is only in the Mazovian Interglacial that a characteristic horizon is formed with *Taxus* abundance averagely reaching 30–40%. In central and southern Poland reaching exceptionally high values, up to 62% (Nita 1999). In most analysed successions, the percentage content of *Taxus* was <10%, with the exception of Skrzynka, where it reached values up to 25%. These values, although lower than in southern and central Poland, conform with those characteristics for eastern Poland (Winter 2008).

Another key feature of the Mazovian Interglacial plant succession is the presence of the intra-interglacial OHO cooling (Koutsodendris *et al.* 2010; Hrynowiecka and Winter 2016; Hrynowiecka and Pidek 2017; Górecki *et al.* 2022). It is visible in the record of all analysed profiles except Wólka Domaszewska, where even a sampling resolution of 1 cm did not allow us to obtain a clear record of vegetation change within the climatic optimum. In the remaining profiles the OHO is typically developed, which is reflected in the rapid decline of trees of temperate climate and a recurring domination of pioneer plants – mainly Pinus and *Betula* (Koutsodendris *et al.* 2010).

The next feature confirming the Mazovian Interglacial age of the sediments is the presence of pollen of thermophilous taxa such as *Pterocarya*, *Buxus*, *Parrotia*, *Celtis* and *Carya* during the climatic optimum (*Carpinus*–*Abies* phase). The presence of *Pterocarya* is particularly important, especially in the last phase of the optimum when the pollen of this taxon is exceptionally abundant (Winter 2008).

A less significant climatic event from the stratigraphic point of view is the record of the Younger Holsteinian Oscillation (YHO), which is known from a much lower number of sites than the OHO (Koutsodendris *et al.* 2010; Hrynowiecka and Winter 2016; Hrynowiecka and Pidek 2017; Hrynowiecka




Text-fig. 10. Pollen diagram for Przytulin (H. Winter).

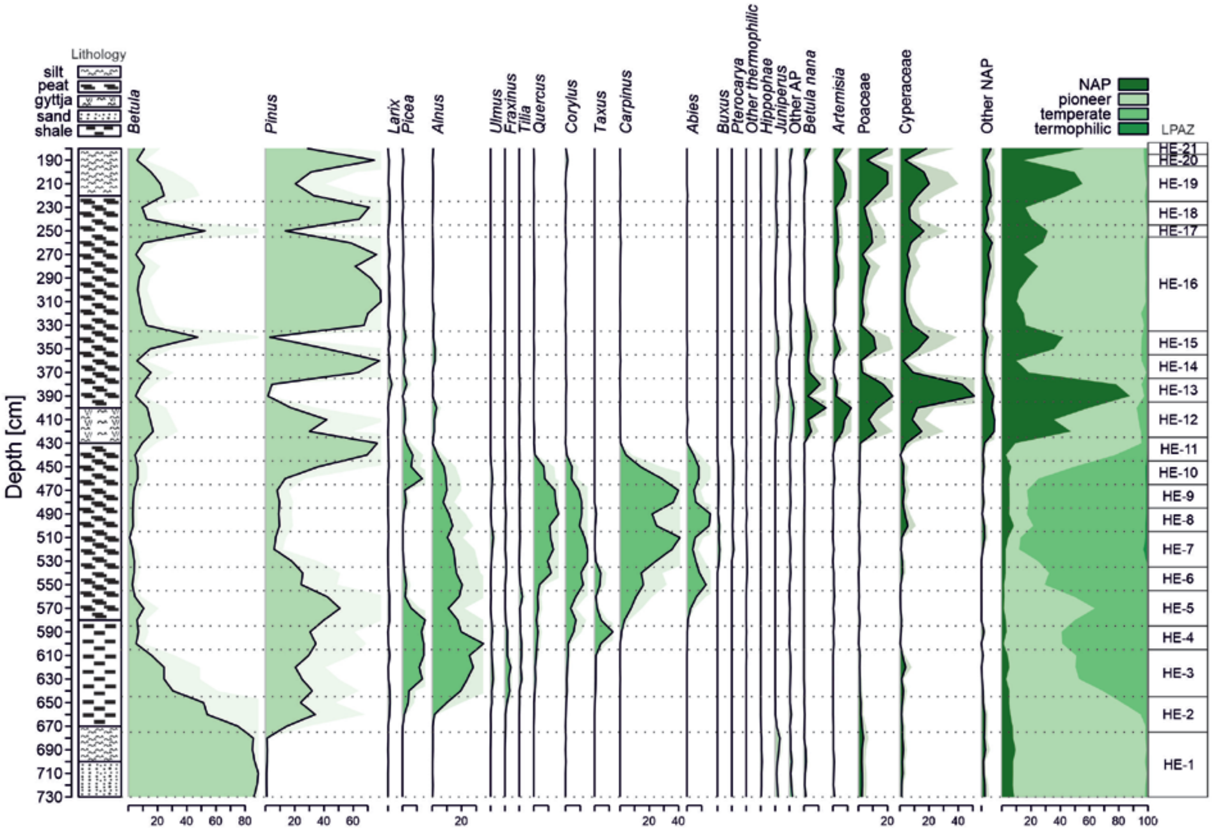
*et al.* 2019; Górecki *et al.* 2022). Among the analysed sites, only the pollen record from Skrzynka and Hermanów reveals an interval corresponding to YHO (Younger Holsteinian Oscillation), which is related to the decline of *Carpinus* forests and their replacement by *Abies* forests (Hrynowiecka *et al.* 2019; Górecki *et al.* 2022).

The last oscillation-type event is the birch oscillation (BHO – Birch Holsteinian Oscillation) firstly recorded in Nowiny Żukowskie (Hrynowiecka-Czmielewska 2010), and later confirmed also in Skrzynka (Górecki *et al.* 2022). Among the studied profiles, it is probably recorded in Wólka Domaszewska (WD-8). The oscillation is linked with a rapid decline of *Pinus* forests replaced by sparse *Betula* forests within *Pinus* pahse.

The pollen record from Skrzynka, Wólka Domaszewska, and Hermanów exceeds the classical concept of the Mazovian Interglacial (MIS 11c). Zones after the *Pinus*-phase conform with the record of the early Liviecian Glaciation (Bińka and Nitychoruk 1995; Hrynowiecka-Czmielewska 2010). Historically, this interval was correlated with MIS 10 (Lindner *et al.* 2013), but studies in Hermanów (Hrynowiecka *et al.* 2019) coupled with new stratigraphic subdivisions of the Pleistocene in Poland (Bińka and Marks 2018) have pointed to the correspondence of this interval with MIS 11b and MIS 11a (Table 6). Based on this comparison, the basin in Hermanów still existed during MIS 11a, whereas the basins in Wólka Domaszewska and Skrzynka were restricted to MIS 11b.

Geological and geomorphological arguments supported by pollen data allow the drawing of the conclusion that the maximum extent of the Odranian Glaciation (Saalian, MIS 6) is marked in the north of the area by the Siedlce–Łosice–Kornica end moraine zone (Text-fig. 13). Further to the south, the limit is marked by a zone at the boundary between the Łuków Plain and the Żelechów Heights, covered by deposits of the Odranian Glaciation (Saalian, MIS 6) and about 20 m thick.

Palaeogeographic analysis of the studied palaeobasins with evidence from the palynologically doc-



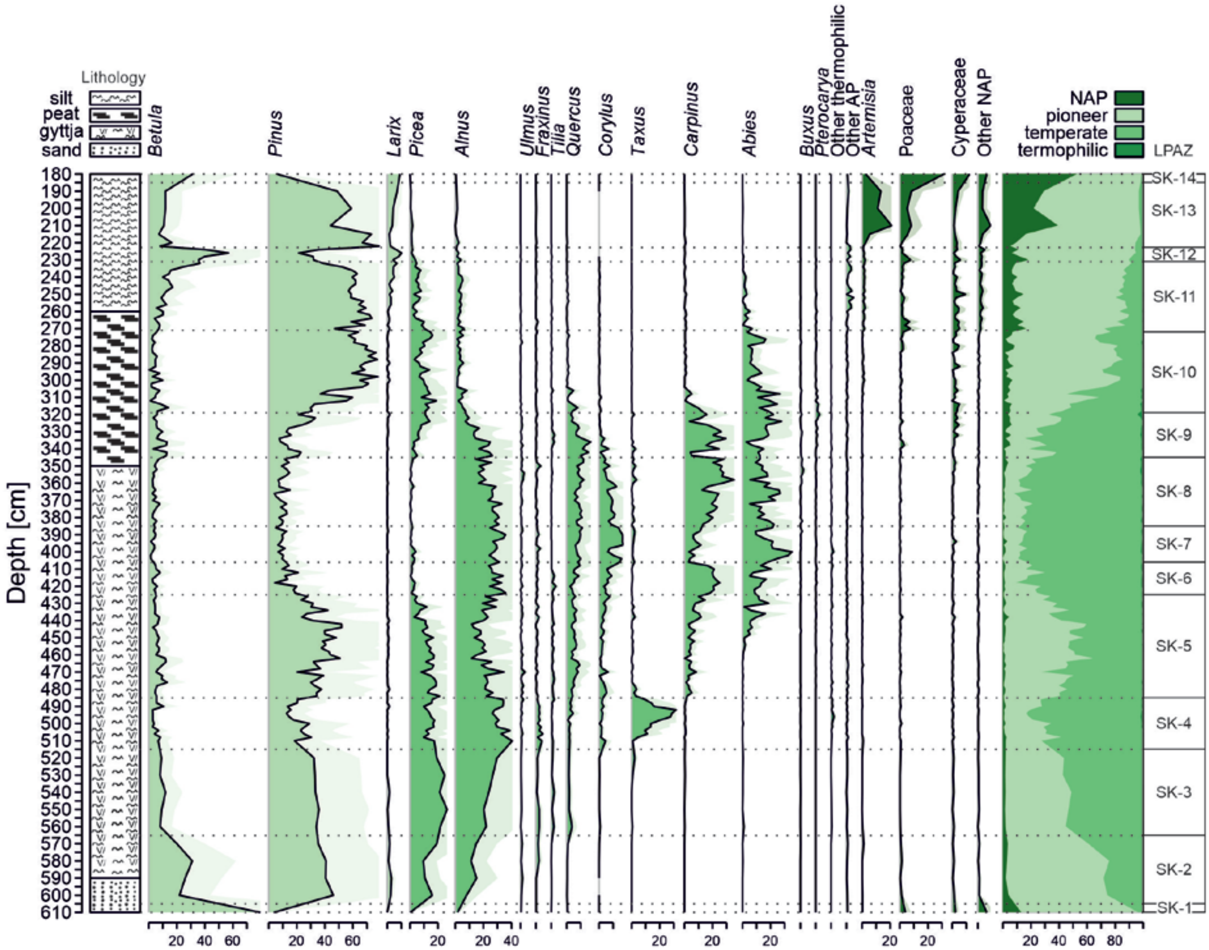

Text-fig. 11. Pollen diagram for Hermanów (A. Hrynowiecka, modified after Hrynowiecka *et al.*2019).

umented deposits of the Mazovian demonstrates the lobe-like character of the Odranian ice sheet margin between Łuków and Kock, with a meridional eastern limit (Text-fig. 13). The Żelechów Heights were covered by the Odranian ice sheet, whereas the western part of the Łuków Plain was situated on the eastern side of the lobe of the Odranian ice sheet (MIS 6), in the extraglacial zone, therefore it is not characterized by a distinct end moraine zone.

In the south-eastern part of the Łuków Plain occurs a vast outwash plain (Pochocka-Szwarc and Żarski 2023), which developed beyond the zone of the maximum Odranian (MIS 6) ice sheet limit along the Siedlce–Łosice–Kornica line. Dominating morphological features are the Wieprz and Krzna ice-marginal valleys, along which meltwater from the Odranian ice sheet was transported to the east towards Pripyat (Text-fig. 13). Valleys of smaller rivers: Wilga, Okrzejka, Bystrzyca, Mała Bystrzyca, Krzna Południowa and Krzna Północna incise the post-glacial plateaus of the Łuków Plain and attain a parallel orientation. Meltwater from the ice sheet in its maximum extent was also transported along these valleys (Text-fig. 13).

The fact that the Łuków Plain is covered by palaeolakelands from the Mazovian Interglacial is proof that the study area was not covered by the Odranian ice sheet (Text-fig. 13) and above lacustrine sediments there are no glacial deposits in the entire succession. The described interglacial sites are part of this palaeolakeland.

An unsolved issue is the very large stratigraphic gap between the Mazovian Interglacial (MIS 11c, Holsteinian), the early part of the Liviecian Glaciation (MIS 11b–a) and the Vistulian (Weichselian, MIS 5d–2). Climate cooling related to MIS 11b–a (Liviecian Glaciation) is recorded in lake and bog deposits at Hermanów and Skrzynka (Text-fig. 7). We assume that south-eastern Poland was not covered by the ice sheets of the Liviecian (MIS 10) and Krznanian glaciations (MIS 8) (see Table 2). It should, however, not be excluded that only northern Poland was covered by the ice sheets of these glaciations (MIS 10, MIS 8).




Text-fig. 12. Pollen diagram for Skrzynka (A. Górecki modified after Górecki *et al.* 2022).

During the Zbójnian (Wacken, MIS 9), Lublinian/Lubavian (Schöningen, MIS 7) and Eemian (MIS 5e) interglacials, there were no lake basins of glacial origin in the study area where fossil lake deposits could have accumulated.

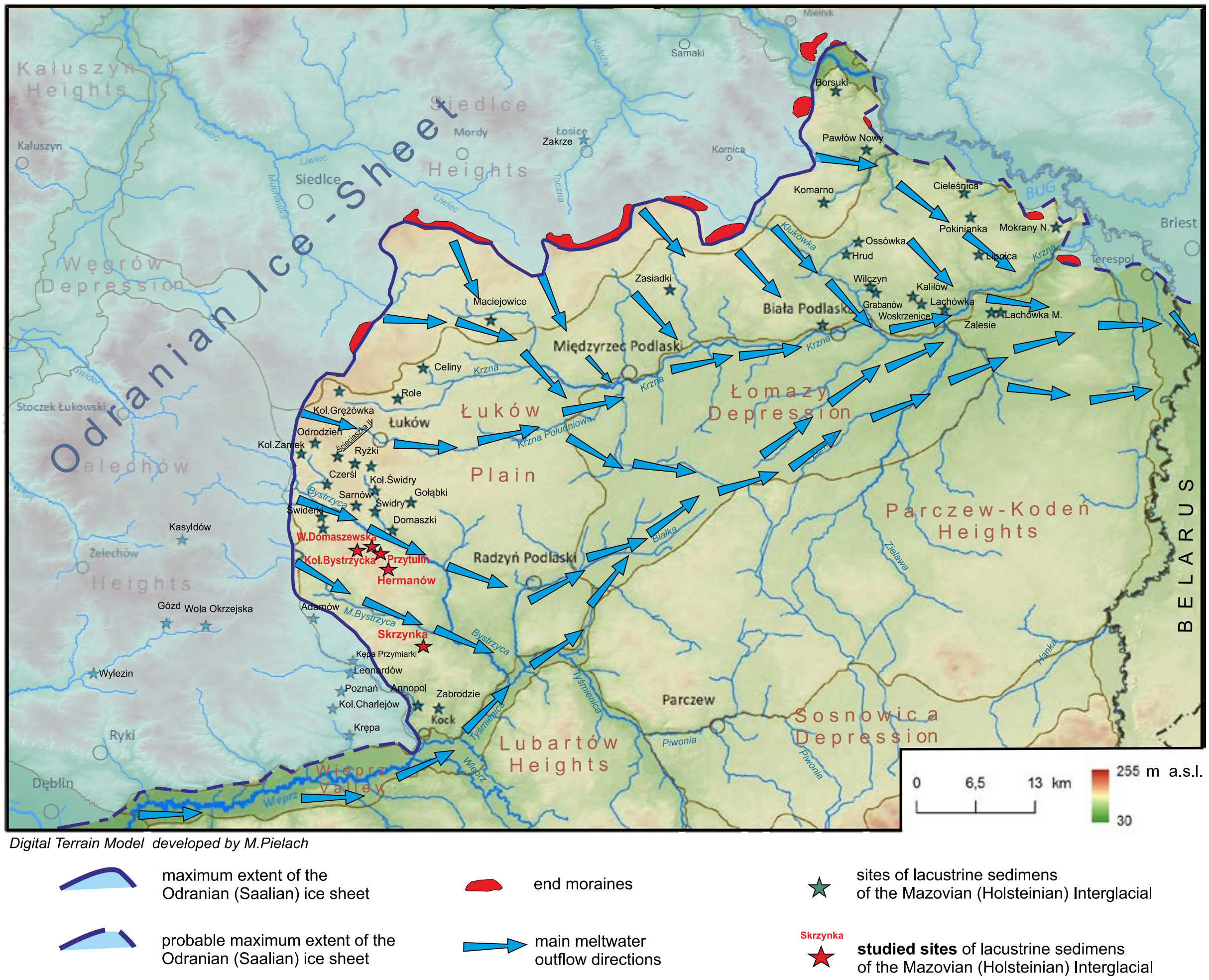
The Odranian ice sheet (MIS 6) did not cover the study area, as also testified by the lack of lake basins with Eemian deposits. The ice sheet front was located 30−40 km to the north of the study area, and its eastern part was situated over a dozen kilometres to the west of the analysed sites (Text-fig. 13). During the Vistulian, in the anaglacial period (MIS 5e−MIS 2), the study area was in the periglacial zone in the presence of permafrost (Dobrowolski 2006).

In the late Vistulian, probably during the Bøling and Alerød warmings, degradation of permafrost caused a slight deflection (from 1.3 to 2 m) of the area within the analysed palaeobasins. This deflection was the consequence of the compaction of biogenic sediments. By the end of the Vistulian, the depressions were filled with sandy-silty sediments (Text-fig. 7).

Later in the Holocene, in the Atlantic period, i.e., in a warmer climate, peatlands developed in some depressions (Hermanów); these peatlands persist till the present. Sites with biogenic interglacial sediments occurring in the subsurface zone are of crucial significance in reconstructing the palaeogeography of a given area, including the determination of the Odranian ice sheet limits (Saalian, MIS 6).

## CONCLUSIONS

- Palynological studies of sites with lake deposits of the Mazovian Interglacial have allowed the depiction of the maximal extent of the Odranian ice




Text-fig. 13. Maximum extent of the Saalian ice-sheet in South Podlasie Lowland; based on: Żarski 2004, Harasimiuk *et al.* 2004a, b, Godlewska 2015, Marks *et al*. 2018, Żarski and Kucharska 2019, Kucharska *et al.* 2019, Hrynowiecka *et al.* 2019, Górecki *et al.* 2022.

sheet along the Łuck–Kock line; this extent has a meridional (lobe-like) extent.

- Distribution of palaeobasins with deposits of the Mazovian Interglacial enabled the determination of the eastern margin of the Odranian (Saalian, MIS 6) ice sheet lobe, which was situated from several to over a dozen kilometres from the analysed sites.
- The maximum extent of the Odranian ice sheet is marked by the Siedlce–Łosice–Kornica end moraine zone, which has been so far considered as a stadial-rank limit of the Odranian Glaciation or the maximum limit of the Wartanian Glaciation.
- The area of the Łuków Plain was not covered by the ice sheet of the Odranian Glaciation. This is demonstrated by the fact that lacustrine deposits of the Mazovian Interglacial infilling the palaeobasins occur directly below the surface and are not covered by glacial deposits.
- Lake deposits occur in post-glacial palaeobasins, which developed after the melting of dead-ice blocks by the end of the Sanian 2 (Elsterian, MIS 2) Glaciation. These palaeobasins are carved in Sanian 2 glacial tills.
- Lake deposits in the analysed sites represent the Mazovian Interglacial vegetation succession with all its typical features.
- Lake deposits of the Mazovian Interglacial (Przytulin, Kolonia Bystrzycka, Wólka Domaszewska sites) or the early Liviecian Glaciation (MIS 11b and a – Hermanów, Skrzynka) are covered by a thin layer (up to 1.82 m) of diluvial, lacustrine and peat mineral deposits from the Vistulian and Holocene.

- The distribution of palaeobasins with deposits of the Mazovian Interglacial has allowed us to determine the eastern limit of the lobe of the Odranian Glaciation (MIS 6), which occurred from several to over a dozen kilometres from the studied sites.

### Acknowledgements

We would like to thank Reviewers for a positive and constructive review. Gratitude is expressed to Bogusław Marcinkowski for heavy mineral analyses, grain size composition of the sandy sediments, and petrographic composition of gravels, and Krzysztof Krupiński for expertise palynologic analysis of sections prepared in the frame of the Detailed Geological Map of Poland at the scale of 1:50 000. We would also like to thank Monika Pielach for preparing a Digital Terrain Model for the study area.

## REFERENCES

Albrycht, A. 2001a. Objaśnienia do SMGP w skali 1:50 000, arkusz Łosice (530), 48 pp. PIG-PIB; Warszawa.

Albrycht, A. 2001b. Szczegółowa Mapa Geologiczna Polski w skali 1: 50 000, arkusz Łosice (530). PIG-PIB; Warszawa.

Albrycht, A. 2004. Objaśnienia do SMGP w skali 1:50 000, arkusz Sarnaki (531), 50 pp. PIG-PIB; Warszawa.

Albrycht, A. 2005. Szczegółowa Mapa Geologiczna Polski w skali 1: 50 000, arkusz Sarnaki (531). PIG-PIB; Warszawa.

Albrycht, A., Bińka, K., Brzezina, R., Dyjor, K., Nitychoruk, J., Pawłowskaja, I. 1997. New sites of interglacial deposits against a background of stratigraphy of younger Quaternary of southern Podlasie, eastern Poland. *Przegląd Geologiczny*, **45**, 629–634. [In Polish with English summary]

Albrycht, A., Skompski, S. and Pidek, I.A. 1995. Significance of mollusc fauna from Ortel Królewski and Rossosz sites for the Quaternary stratigraphy of Podlasie (East Poland). *Przegląd Geologiczny*, **43**, 321–330. [In Polish with English summary]

Barczuk, A. and Nejbert, K. 2007. Analiza minerałów nieprzezroczystych w badaniach skał okruchowych. In: Mycielska-Dowgiałło, E. (Eds), Badania cech teksturalnych osadów czwartorzędowych i wybrane metody oznaczania ich wieku, 205–228. Wydawnictwo Szkoły Wyższej Przymierza Rodzin; Warszawa.

Ber, A., Lindner, L. and Marks, L. 2007. Propozycja podziału stratygraficznego czwartorzędu Polski *Przegląd Geologiczny,* **55**, 115–118.

Berglund, B.E. and Ralska-Jasiewiczowa, M. 1986. Pollen analysis and pollen diagrams. In: Berglund. B.E. (Ed.), Handbook of Holocene palaeoecology and palaeohydrology, 455–484. John Wiley; Chichester.

Bińka, K. and Nitychoruk J. 1995. Mazovian (Holsteinian) lake sediments at Woskrzenice near Biała Podlaska. *Geological Quarterly*, **39** (1): 109–120.

Bińka, K. and Nitychoruk, J. 1996. Geological and palaeobotanical setting of inter glacial sediments at the Kaliłów site in southern Podlasie *Geological Quarterly*, **40** (2): 269–82.

Bińka, K., Lindner, L. and Nitychoruk, J. 1997. Geologic-floristic setting of the Mazovian Interglacial sites in Wilczyn and Lipnica in southern Podlasie (eastern Poland) and their palaeogeographic connections. *Geological Quarterly*, **41** (3): 381–394.

Błaszkiewicz, M. 2005. Late Glacial and Early Holocene evolution of the lake basins in the Kociewskie Lakeland (Eastern part of the Pomeranian Lake). *Prace Geograficzne*, **32**, 1–192 [In Polish with English abstract and summary]

Błaszkiewicz, M. 2008. Wytapianie się pogrzebanych brył martwego lodu w późnym glacjale i wczesnym holocenie a zdarzenia ekstremalne. *Landform Analysis*, **8**, 9–12.

Błaszkiewicz, M. 2011. Timing of the final disappearance of permafrost in the Central European Lowland as reconstructed from the evolution of lakes in N Poland. *Geological Quarterly*, **55** (4): 361–37.

Bogucki, A. and Łanczont, M. 2018. Stratygrafia kompleksów lessowo-glebowych strefy perglacjalnej zachodniej części Ukrainy. Materiały XX Polsko-Ukraińskiej Seminarium Terenowe „Klimatyczne cykle plejstocenu w zapisie sekwencji osadowej Niziny Podlaskiej" (Mielnik, 2–5 lipca 2018 r.), 9–10. Wydawnictwo UMCS; Lublin.

Brzezina, R. 2000a. Szczegółowa Mapa Geologiczna Polski 1:50 000, arkusz Krzesk (566). NAG PIG-PIB; Warszawa.

Brzezina, R. 2000b. Objaśnienia do Szczegółowej Mapy Geologicznej Polski 1:50 000, arkusz Krzesk (566). NAG PIG-PIB; Warszawa.

Buraczyński, J. and Wojtanowicz J. 1980/1981. The Effect of the Middle-Polish Glaciation on the Relief of Southern Part of Polesie Lubelskie. *Annales UMCS Sect. B*, **35/36**, 65–79. [In Polish with English summary]

Buraczyński, J. 1986. Extent of the Odra (Saalian) in the Eastern Poland. *Przegląd Geologiczny*, **34** (12), 684–689. [In Polish with English summary]

Cailleux, A. 1942. Les actions éoliennes périglaciaires en Europe. *Memoires Société Géologique de France*, **41**, 46.

Cailleux, A. 1961. Application à la géographie des methods d'étude des sables et des galets, 1–61. Universidade do Brasil, Faculdade Nacional de Filosofia; Rio de Janeiro.

Cohen, K.M. and Gibbard, P.L. 2011. Global chronostratigraphical correlation table for the last 2.7 million years. International Commision on Stratigraphy; Cambridge.

Cohen, K.M. and Gibbard, P. 2019. Global chronostratigraphical correlation table for the last 2.7 million years, version 2019 QI-500. *Quaternary International* **500**, 20–31.

Czubla, P., Godlewska, A., Terpiłowski, S., Zieliński, T., Zieliński, P., Kusiak, J., Pidek, I.A. and Małek, M. 2013. Glacial till petrography of the South Podlasie Lowland (E Poland) and stratigraphy of the Middle Pleistocene Complex (MIS 11–6). In: Damušytė, A. and Grigienė, A. (Eds), Palaeolandscapes from Saalian to Weichselian, South Eastern Lithuania. Abstracts of International Field Symposium, Vilnius-Trakai, Lithuania, 27–29. Lithuanian Geological Survey; Vilnius.

Czubla, P., Terpiłowski, S., Orłowska, A., Zieliński, P., Zieliński, T. and Pidek, I. A., 2019. Petrographic features of tills as a tool in solving stratigraphical and palaeogeographical problems – A case study from Central-Eastern Poland. *Quaternary International*, **501**, 45–58.

Dyakowska, J. 1956. Pleistocene profile from Wylezin, Central. Poland *Biuletyn Instytutu Geologicznego*, **100**: 193–216. [In Polish with English summary]

Erdtman, G. 1960. The acetolysis method: A revised description. *Svensk Botanisk Tidskrift*, **54**, 561–564.

Folk, R.L. and Ward, W.L. 1957. Brazos River bar: a study in the significance of grain size parameters. *Journal of Sedimentary Research*, **27**, 3–26.

Godlewska, A. 2014. Dynamics of the younger saalian ice sheet in the marginal zone in the interfluve of the Krzna and Bug River, 153 pp. Wydawnictwo UMCS; Lublin. [In Polish with English summary]

Godlewska, A. 2015. New approach to dynamics of Younger Saalian ice sheet (Warthe) in marginal zone in the interfluve of the Krzna and Bug rivers (Eastern Poland), *Acta Geographica Lodzensis*, **103**, 45–57. [In Polish with English summary]

Górecki A., Żarski, M., Drzewicki, W., Pleśniak, Ł, Zalewska-Gałosz, J. and Hrynowiecka, A. 2022. New climatic oscillations during MIS 11c in the record of the Skrzynka II site (Eastern Poland) based on palynological and isotope analysis. *Quaternary International*, **632**, 4–20.

Harasimiuk, M. and Terpiłowski, S. (Eds) 2004a. Zlodowacenie Warty w Polsce, 171 pp. Wydawnictwo Universitatis Mariae Curie-Sklodowska; Lublin.

Harasimiuk, M., Szwajger, W. and Terpiłowski, S. 2004b. Effect of the Warta Glaciations ice sheet on relief of the northern foreland of the Lublinian Upland. In: Harasimiuk, M. and Terpiłowski, S. (Eds), Zlodowacenie Warty w Polsce, 163–171. Wydawnictwo Universitatis Mariae Curie-Sklodowska; Lublin [In Polish with English summary]

Head, M.J. and Gibbard, P.L. 2015. Early–Middle Pleistocene transitions: linking terrestial and marine realms. *Quaternary Internacional*, **389**, 7–46.

Hrynowiecka, A. and Żarski, Winter, H. 2014. Vegetation and stratigraphy of the Mazovian (Holsteinian) Inter glacial sections from Dobropol and other new sites in Western Polesie Region, South-Eastern Poland. *Studia Quaternaria*, **31**, 17–30.

Hrynowiecka, A., Żarski, M. and Drzewicki, W. 2019. The rank of climatic oscillations during MIS 11c (OHO and YHO) and post-interglacial cooling during MIS 11b and MIS 11a in eastern Poland. *Geological Quarterly*, **63** (2), 375–394.

Hughes, P.D., Gibbard P.L. and Ehlers J. 2020. The “missing glaciations” of the Middle Pleistocene. *Quaternary Research* (50th Anniversary Issue), **96**, 161–183.

Jahn, A. 1956. Wyżyna Lubelska. Rzeźba i czwartorzęd. *Prace Geograficzne Instytu Geografii PAN*, **7**, 1–453.

Janczyk-Kopikowa, Z. 1996. Temperate stages of the Mesopleistocene in NE Poland. *Biuletyn Państwowego Instytutu Geologicznego*, **373**, 49–66. [In Polish with English summary]

Jersak, J. 1973. Lithology and stratigraphy of the loess on the Southern Polish Uplands. *Acta Geographica Lodziensia* **32**, 139 pp. [In Polish with English summary]

Jesionkiewicz, P. 1982. A new locality of Masovian Interglacial deposits at Krępa near Kock. *Geological Quarterly*, **26** (2), 423–430. [In Polish with English summary]

Kenig, K. 1998. Petrographic foundations of till stratigraphy of northeastern Poland. *Biuletyn Państwowego Instytutu Geologicznego*, **380**, 1–99. [In Polish with English summary]

Koutsodendris, A., Pross, J., Müller, U.C., Brauer, A., Fletcher, W.J., Kühl, N., Kirilova, E., Verhagen, F.T. M., Lücke, A. and Lotter, A.F. 2012. A short-term climate oscillation during the Holsteinian interglacial (MIS 11c): An analogy to the 8.2 ka climatic event? *Global and Planetary Change*, **92–93**, 224–235.

Krupiński, K.M. 1988. Plant succesion of the Biała Podlaska *Przegląd Geologiczny*, **36** (11): 647–655. [In Polish with English summary]

Krupiński, K.M. 1995. Pollen stratigraphy and successions of vegetation during the Mazovian Interglacial. *Acta Geographica Lodziensia*, **70**, 3–200. [In Polish with English summary]

Krupiński, K.M. 1996a. Sediments of the Mazowvian Interglacial at Pawłów Nowy (Podlasie Region) eastern Poland. *Przegląd Geologiczny*, **44** (2): 168–172. [In Polish with English summary]

Krupiński, K.M. 1996b. Vegetation and climate of the early neoplejstocene of southern Podlasie. *Biuletyn Instytutu Geologicznego*, **373**, 79–86. [In Polish with English summary]

Krupiński, K.M. 1997. The succesion of interglacial vegetation at Mokrawy Nowe in Podlasie. *Acta Palaeobotanica*, **37** (1), 81–93.

Krupiński, K.M. 2000. Palynostratigraphic correlation of deposits of the Mazovian Interglacial of Poland. *Prace Państwowego Instytutu Geologicznego*, **169**: 1–61. [In Polish with English summary]

Krupiński, M. 2004a. Opracowanie zawartości paleobotanicznej wybranych próbek osadów z otworu wiertniczego Wólka Domaszewska WH 38, arkusz Adamów. In: Żarski, M., Szczegółowa Mapa Geologiczna Polski w skali 1:50 000, arkusz Adamów (637). Suplement. NAG PIG PIB 439/2006. Państwowy Instytut Geologiczny; Warszawa.

Krupiński, M. 2004b. Opracowanie zawartości paleobotanicznej wybranych próbek osadów z otworu wiertniczego Kolonia Bystrzycka WH 39, arkusz Adamów. In: Żarski, M., Szczegółowa Mapa Geologiczna Polski w skali 1:50 000, arkusz Adamów (637). Suplement. NAG PIG PIB 439/2006. Państwowy Instytut Geologiczny; Warszawa.

Krupiński, M. 2004c. Ekspertyza: opracowanie zawartości paleobotanicznej wybranych próbek osadów z otworu wiertniczego Skrzynka 2127, arkusz Adamów. In: Żarski, M., Szczegółowa Mapa Geologiczna Polski w skali 1:50 000, arkusz Adamów (637). Suplement. NAG PIG PIB 439/2006. Państwowy Instytut Geologiczny; Warszawa.

Krupiński, K.M. and Żarski, M. 2004. Wyniki nowych badań geologicznych i paleobotanicznych osadów interglacjału mazowieckiego z Wylezina. *Geografia*, **68** (4), 211–229. Wydawnictwo Uniwersytetu Adama Mickiewicza; Poznań.

Krupiński, K.M., Żarski, M. and Nawrocki, J. 2004. Geological-stratigraphic reinterpretation of Mazovian Interglacial sediments at Wylezin near Ryki (eastern Poland). *Przegląd Geologiczny*, **52** (8/1), 683–692. [In Polish with English summary].

Krupiński, K.M. 2009. Badania paleobotaniczne osadów biogenicznych z Hermanowa. In: Żarski, M. and Lisicki, S. (Eds), Strefa marginalna lądolodu zlodowacenia Warty i pojezierza plejstoceńskie na południowym Podlasiu. XVI Konferencja Stratygrafia Plejstocenu Polski. Zimna Woda k. Łukowa, 31.08–4.09.2009, 185–188. Państwowy Instytut Geologiczny; Warszawa.

Krygowski, B. 1956. Glanurometric investigations on the Pleistocene of Western Poland. *Biuletyn Instytutu Geologicznego*, **100**, 503–608. [In Polish with English summary]

Krygowski, B. 1964. Graniformometria mechaniczna – zastosowanie, teoria. *Prace Komisji Geograficzno-Geologicznej Poznańskie Towarzystwo Przyjaciół Nauk*, **2** (4), 1–112.

Krygowski, B. 1967. Zmienność glin morenowych w zakresie uproszczonego składu petrograficznego. *Zeszyty Naukowe UAM, Geografia*, **7**, 59–65.

Kucharska, M., Żarski, M., Przasnyska, J. and Tekielska, A. 2019. Mapa geologiczna Polski w skali 1: 200 000, arkusz Siedlce. Państwowy Instytut Geologiczny - Państwowy Instytut Badawczy; Warszawa.

Lindner, L. 1984. An outline of Pleistocene chronostratigraphy in Poland. *Acta Geologica Polonica*, **34** (1–2), 27–48.

Lindner, L. 1988. Outline of pleistocene stratigraphy of Biała Podlaska region (Eastern Poland) and attempt of corelation with neighboring area of the Soviet Union. *Przegląd Geologiczny*, **36** (11), 637–647. [In Polish with English summary]

Lindner, L. 1996. Pomazowieckie osady lodowcowe i wodnolodowcowe w rejonie Białej Podlaskiej i ich wiek w świetle dyskusji nad problemem zlodowacenia Warty w Polsce. *Biuletyn Instytutu Geologicznego*, **337**, 87–96.

Lindner, L. 2005. A new look at the number, age and extent of the Middle Polish Glaciations in the southern part of central-eastern Poland. *Przegląd Geologiczny*, **53** (2), 145–150. [In Polish with English summary]

Lindner, L., Maruszczak, H. and Wojtanowicz, J. 1985. Extents and chronology of early stadial advances of the Mid Polish (Saalian) ice sheet between the upper Warta and Bug Rivers. *Przegląd Geologiczny*, **33** (2), 57–64. [In Polish with English summary]

Lindner, L., Krupiński, K.M., Marciniak, B. and Nitychoruk, J. 1990. Geological and floristic situation of pleistocene organogenic deposits in the Ossówka Region (Southern Poland). *Przegląd Geologiczny*, **38** (11), 476–483. [In Polish with English summary]

Lindner, L., Krupiński, K.M., Marciniak, B., Nitychoruk, J. and Skompski, S. 1991. Pleistocene lake sediments of the site Hrud I near Biała Podlaska. *Geological Quarterly*, **35** (3), 337–362.

Lindner, L., Maruszczak, H., Palienko, V.P. and Wojtanowicz, J. 1991. Extents and chronology of stadial advances of the Saalian I ice sheet between the Odra and Dniepr rivers. *Annales Universitatis Mariae Curie-Sklodowska, sectio B*, **46**, 139–153.

Lindner, L. and Marks, L. 1995. Outline of paleomorphology of the Polish territory during the scandinavian glaciations. *Przegląd Geologiczny*, **47** (7), 591–595. [In Polish with English summary]

Lindner, L. and Wyrwicki, R. 1996. Pleistocene lacustrine deposits in Grabanów (Podlasie, Eastern Poland). *Przegląd Geologiczny*, **44** (11) 1131–1134. [In Polish with English summary]

Lindner, L. and Marciniak, B. 1997. Środkowoplejstoceńskie jeziora kopalne na tle stratygrafii czwartorzędu w rejonie Janowa Podlaskiego (wschodnia Polska). *Przegląd Geologiczny*, **45** (5), 484–488.

Lindner, L. and Marciniak, B. 1998. Middle Pleistocene lake deposits in southern Podlasie (eastern Poland). *Studia Geologica Polonica*, **113**: 65–83.

Lindner, L. and Marks, L. 1999. New approach to stratigraphy of palaeolake and glacial sediments of the younger Middle Pleistocene in mid-eastern Poland. *Geological Quarterly*, **43**, 1–8.

Lindner, L., Bogucki, A., Chlebowski, R. and Gożik, P. 2004a. Nowe spojrzenie na zasięgi lądolodów skandynawskich w czasie zlodowaceń środkowopolskich (dnieprowskich) na obszarze Polski i Ukrainy. In: Michalczyk, Z. (Ed.), Badania geograficzne w poznaniu środowiska, 97–99. Wydawnictwo Universitatis Mariae Curie-Sklodowska; Lublin.

Lindner, L., Gozhik, P., Marciniak, B., Marks, L. and Yelovicheva, Y. 2004b. Main climatic changes in the Quaternary of Poland, Belarus and Ukraine. *Geological Quarterly*, **48** (2), 97–114.

Lindner, L. Bogutsky, A., Chlebowski, R., Gozhik, P.M., Jełowiczewa, J., Wojtanowicz, J. and Zaleskii, I. 2007. Stratygrafia czwartorzędu Polesia Wołyńskiego (NW Ukraina). *Annales Universitatis Mariae Curie-Sklodowska, sec. B*, **62**, 7–41.

Lindner, L. and Marks L. 2012. Climatostratigraphic subdivision of the Pleistocene Middle Polish Complex in Poland. *Przegląd Geologiczny*, **60**, 36–45. [In Polish with English summary].

Lindner, L., Marks, L. and Nita, M. 2013. Climatostratigraphy of interglacial in Poland: Middle and Upper Pleistocene lower boundaries from a Polish Perspective. *Quaternary International*, **292**: 113–123.

Lindner, L., Bogucki, A., Jełowiczewa, J., Marciniak, B. and Wojtanowicz, J. 2004c. Problem braku przykrycia morenowego większości stanowisk osadów interglacjału mazowieckiego (aleksandryjskiego, lichwińskiego) w przygranicznych obszarach Polski, Białorusi i Ukrainy. In: Ber, A., Krysiak, Z. and Lisicki, S. (Eds), Zlodowacenia i interglacjały wschodniej Polski. Problemy plejstocenu Wysoczyzny Białostockiej. XI Stratygrafia Plejstocenu Polski, Supraśl 30 sierpnia – 3 września 2004, 54–55. Państwowy Instytut Geologiczny; Warszawa.

Lisicki, S. 2003. Lithotypes and lithostratigraphy of tills of the pleistocene in the Vistula drainage basin area, Poland. *Prace Państwowego Instytutu Geologicznego*, **177**, 1–105. [In Polish with English summary].

Lisiecki, L.E. and Raymo, M.E. 2005. A Pliocene-Pleistocene stack of 57 globally distributed benthic d $^{18}$O records: Pliocene–Pleistocene benthic stack. *Paleoceanography*, **20**, 1–17.

Litt, T., Behre, K.E., Meyer, K.D., Stephan, H.J. and Wansa, S. 2007. Stratigraphische Begriffe für das Quartär des norddeutschen Vereisungsgebietes. Eiszeitalter und Gegenwart. *Quaternary Science Journal*, **56** (1/2), 7–65.

Małek, M. 2004a. Szczegółowa Mapa Geologiczna Polski 1: 50 000, arkusz Siedlce Południe (565). NAG PIG PIB; Warszawa.

Małek, M. 2004b. Objaśnienia do Szczegółowej Mapy Geologicznej Polski 1:50 000, arkusz Siedlce Południe (565). NAG PIG-PIB; Warszawa.

Małek, M. and Pidek, I.A. 2007. Palinostratygraphy of organogenic deposits of new interglacial stands on the Łuków Plain. *Annales Universitatis Mariae Curie-Sklodowska sectio B*, **47** (2): 43–57. [In Polish with English summary]

Małek, M. and Buczek, K. 2008. Objaśnienia do Szczegółowej mapy geologicznej Polski w skali 1: 50 000, arkusz Łuków (602). NAG PIG-PIB; Warszawa.

Małek, M. and Buczek, K. 2009. Szczegółowa mapa geologiczna Polski 1: 50 000, arkusz Łuków (602). NAG PIG-PIB; Warszawa.

Małek, M. 2011. Objaśnienia do Mapy geologicznej Polski w skali 1: 200 000, arkusz Łuków. NAG PIB -PIB; Warszawa.

Marcinkowski, B. and Mycielska-Dowgiałło, E. 2013. Heavy minerals analysis in Poland investigations of Quaternary deposits: a review. *Geologos*, **19** (1–2), 5–23.

Marks, L., Lindner, L. and Nitychoruk, J. 1995. New approach to a stratigraphic position of the Warta Stage in Poland. *Acta Geographica Lodziensis*, **68**, 135–147.

Marks, L. 2004a. Zasięg lądolodu zlodowacenia warty w Polsce. In: Harasimiuk, M. and Terpiłowski, S. (Eds), Zlodowacenie Warty w Polsce, 27–35. Wydawnictwo Universitatis Mariae Curie-Sklodowska; Lublin.

Marks, L. 2004b. Pleistocene glacial limits in Poland. In: Ehlers, J. and Gibbard, P.L. (Eds), Quaternary Glaciation – Extent and Chronology. *Developments in Quaternary Sciense*, **2** (1), 295–300.

Marks, L. 2011. Quaternary glaciations in Poland. In: Ehlers, J., Gibbard, P.L. and Hughes P.D. (Eds), Quaternary Glaciation – Extent and Chronology, a Closer Look. *Developments in Quaternary Science*, **2** (15), 299–303.

Marks, L. and Pavlovskaya, I. 2006. Correlation of the Saalian glacial limits in eastern Poland and western Belarus. *Geological Quarterly*, **149** (5), 87.

Marks, L. and Karabanow, A. (Eds) 2017. Geological Map of North Belarusian Cross-border Area with Explanatory text. Państwowy Instytut Geologiczny-Państwowy Instytut Badawczy; Warszawa.

Marks, L., Karabanov A., Nitychoruk, J., Bahdasarau, M., Krzywicki, T., Majecka, M., Pochocka-Szwarc, K., Rychel J., Woronko, B., Zbucki, Ł., Hradunova, A., Hrychanik, M., Mamchyk, S., Rylova, T., Nowacki, Ł. and Pielach M. 2018. Revised limit of Saalian ice sheet in central Europe. *Quternary Internaytional*, **478**, 59–74.

Marks, L., Grabowski J., and Stępień U. (Eds) 2022 – Geological Map of Poland in scale 1: 500 000. PIG-PIB; Warszawa.

Marks, L. 2023a. Principles of the Quaternary stratigraphy in Poland and its main categories. *Przegląd Geologiczny*, **71**, 485–502. [In Polish with English summary]

Marks, L. 2023b. Pleistocene glaciations in southern Poland – a revision. *Geological Quarterly*, **67**, 25.

Meyer, K.-J. 1974. Pollenanalytische Untersuchungen und Jahresschichtzählungen an der holstein-zeitlichen Kieselgur von Hetendorf. *Geologisches Jahrbuch* A, **21**, 87–105.

Morawski, J. 1955. Metodyka badań morfologii ziaren piasku za pomocą powiększalnika fotograficznego. *Annales Universitatis Mariae Curie-Sklodowska Sec. B*, **10**, 199–222.

Mojski, J.E. 1971. Objaśnienia do Mapy Geologicznej Polski 1: 200 000, arkusz Łuków. NAG PIG-PIB; Warszawa.

Mojski, J.E. 1972a. Nizina Podlaska. Geomorfologia Polski, 318–362. PWN; Warszawa.

Mojski, J.E. 1972b. Mapa Geologiczna Polski 1: 200 000, arkusz Łuków. NAG PIG-PIB; Warszawa.

Michczyński, A. 2017. Wyniki oznaczenia wieku bezwzględnego metodą radiowęglową próbki torfów ze stanowiska Hermanów, manuskrypt, 1–3. NAG PIG-PIB; Warszawa.

Mycielska-Dowgiałło, E. 1995. Wybrane cechy teksturalne osadów i ich wartość interpretacyjna. In: Mycielska Dowgiałło, E. and Rutkowski, J. (Eds), Badania osadów czwartorzędowych. Wybrane metody i interpretacja wyników, 29–114. Wydział Geografii i Studiów Regionalnych, Uniwersytet Warszawski; Warszawa.

Mycielska Dowgiałło, E. and Rutkowski, J. 1995. Badania osadów czwartorzędowych, wybrane metody i interpretacja wyników, 29–105. Wydział Geografii i Studiów Regionalnych, Uniwersytet Warszawski; Warszawa.

Myślińska, A.E. 2016. Laboratoryjne badania gruntów i gleb, 280 pp. Wydział Geografii i Studiów Regionalnych, Uniwersytet Warszawski; Warszawa.

Nalepka, D. and Walanus, A. 2003. Data processing in pollen analysis. *Acta Palaeobotanica*, **43**, 125–134.

Nita, M. 1999. Mazovian Interglacial at Konieczki near Kłobuck (Silesian–Cracovian Upland). *Acta Paleobotanical*, **39** (1), 89–135.

Nitychoruk, J. 1994. Stratigraphy of the Pleistocene and palaeogeomorphology of Southern Podlasie. *Rocznik Międzyrzecki*, **26**, 23–107. [In Polish with English summary]

Nitychoruk, J. 2000. Climate reconstruction from stable-isotope composition of the Mazovian Interglacial (Holsteinian) lake sediments in eastern Poland. *Acta Geologica Polonica*, **50**, 247–294.

Nitychoruk, J. and Gałązka, D. 2006a. Objaśnienia do Szczegółowej mapy geologicznej Polski 1:50 000, arkusz Biała Podlaska (568). NAG PIG-PIB; Warszawa.

Nitychoruk, J. and Gałązka, D. 2006b. Objaśnienia do szczegółowej mapy geologicznej w skali 1: 50 000, arkusz Rokitno (569). NAG PIG-PIB; Warszawa.

Nitychoruk, J. and Gałązka, D. 2008. Szczegółowa Mapa geologiczna Polski w skali 1:50 000, arkusz Biała Podlaska (568). NAG PIG-PIB; Warszawa.

Nitychoruk, J. and Gałązka, D. 2007. Szczegółowa Mapa geologiczna Polski w skali 1:50 000, arkusz Rokitno (569). NAG PIG-PIB; Warszawa.

Nitychoruk, J., Bińka, K., Hoefs, J., Ruppert, H. and Schneider, J. 2005. Climate reconstruction for the Holsteinian Interglacial in eastern Poland and its comparison with isotopic data from Marine Iso tope Stage 11. *Quaternary Science Reviews*, **24**: 631–644.

Pidek, I.A., Terpiłowski, S. and Małek, M. 2011. Succession of the Mazovian Interglacial nearŁuków (E Poland): palynostratigraphic and palaeogeographic approach. *Geologija*, **53** (1), 27–35.

Pochocka-Szwarc, K., Żarski, M., Pidek, I., Hrynowiecka, A. and Szymanek M. 2021. Nowe stanowiska interglacjału mazowieckiego na Zaklęsłości Sosnowickiej (Polesie Zachodnie) i ich znaczenie paleogeograficzne i stratygraficzne. In: Dobrowolski, R., Orłowska, A., Hołub, B. and Janicki, G. (Eds), Glacjał i Peryglacjał Europy środkowej, 257–263. Wydawnictwo Universitatis Mariae Curie-Sklodowska; Lublin.

Pochocka-Szwarc, K. and Żarski, M. 2023. Geological Map of Polish-Belarusian-Ukrainian border area. Włodawa region. Scale 1: 250 000. NAG PIG-PIB; Warszawa.

Pochocka-Szwarc, K., Żarski, M., Hrynowiecka, A., Górecki, A., Pidek, I.A., Szymanek, M., Stachowicz-Rybka, R., Stachowicz, K. and Skoczylas-Śniaz, S. 2024. Mazovian Interglacial sites in the Sosnowica Depression and the Parczew-Kodeń Heights (Western Polesie, SE Poland), and their stratigraphic, palaeogeographic and palaeoenvironmental significance. *Gological Quarterly*, DOI 10.7306/gq.1747.

Racinowski, R. 1973. Analiza uziarnienia. In: Rühle, E. (Ed.), Metodyka badań osadów czwartorzędowych, 331–335. Wydawnictwo Geologiczne; Warszawa.

Racinowski, R. 1995. Analiza minerałów ciężkich w badaniach osadów czwartorzędowych Polski. Wybrane metody i interpretacji wyników [In Polish]. In: Mycielska-Dowgiałło, E. and Rutkowski, J. (Eds), Badania osadów czwartorzędowych, 151–175. Komisja Litologii i Genezy Osadów Czwartorzędowych PAN, UW i Państwowy Instytut Geologiczny; Warszawa.

Richling, A. (Eds) 2021. Regionalna geografia fizyczna Polski, 608 pp. Bogucki Wydawnictwo Naukowe; Poznań.

Rohling, E.J., Braun, K., Grant, K., Kucera, M., Rob erts, A.P., Siddal, M. and Trommer, G. 2010. Comparison between Holocene and Marine Isotope Stage – 11 sea-level histories. *Earth and Planetary Science Letters*, **291**, 97–105.

Różycki, S.Z. 1972. Plejstocen Polski środkowej na tle przeszłości w górnym trzeciorzędzie, 314 pp. Wydawnictwo PWN; Warszawa.

Różycki, S.Z. 1980. Principles of stratigraphic subdivisions of Quaternary of Poland. *Quaternary Studies in Poland*, **2**, 99–106.

RStudio Team. 2020. RStudio: Integrated development for R. Retrieved from https://www.rstudio.com/

Rzechowski, J. 1977. Main lithotypes of tills in the Central Polish area. *Biuletyn Instytutu Geologicznego*, **305**, 31–43.

Rühle, E. 1968. Profil utworów czwartorzędowych w Wylezinie (na północ od Dęblina). *Rocznik Polskiego Towarzystwa Geologicznego*, **38** (4), 531–543.

Rühle, E. 1970. Nowe jednostki stratygraficzne zlodowacenia środkowopolskiego na obszarze pomiędzy środkową Wisłą a dolnym Bugiem. In: Problemy Czwartorzędu. *Acta Geographica Universitatis Lodziensis*, **24**, 399–419.

Skompski, S. 1991. Pleistocene lake sediments of the site Hrud I near Biała Podlaska *Geological Quarterly*, **35** (3), 337–362.

Sawicki, L. 1922. Wiadomość o środkowopolskiej morenie czołowej. *Rozprawy Polskiej Akademii Umiejętności*, **61**, 26–35.

Schomacker, A. and Benediktsson, Í.Ö. 2018. Supraglacial Environments. In: Menzies, J. and van der Meer, J.J.M. (Eds), Past glacial environments (2nd ed), 159–179. Elsevier; Hoboken.

Siemiradzki, J. 1889. Szkic mapy geologicznej Królestwa Polskiego i krajów przyległych. *Wszechświat*, **8**, 49–55.

Stockmar, R.J. 1971. Tablets with spores used in absolute pollen analysis. *Pollen et Spores*, **13**, 615–621.

Szymanek, M. 2008. *Viviparus diluvianus* (Kunth) in the vicinity of Biała Podlaska as an indicator of climatic environmental changes in the Mazovian (Holsteinian) Interglacial. *Prace Komisji Paleogeografii Czwartorzędu Polskiej Akademii Umiejętności*, **6**, 19–27. [In Polish with English summary]

Szymanek, M. 2011. Climate oscillations of the Holsteinian (Mazovian) Interglacial recorded in shell morphometry of *Viviparus diluvianus* (Kunth, 1865) from eastern Poland. *Quaternary International*, **241**, 143–159.

Szymanek, M. 2012. Malacofauna of the Holsteinian lake deposits at Hrud II (eastern Poland) and its ecological significance. *Geological Quarterly*, **56** (1), 117–126.

Szymanek, M. 2013. Palaeoecology of the Holsteinian lake in vicinity of Wilczyn (eastern Poland) based on molluscan studies. *Geological Quarterly*, **57** (4), 637–648.

Terpiłowski, S. 2001. Strefa marginalna lądolodu warciańskiego na Wysoczyźnie Siedleckiej w świetle analizy litofacjalnej, 98 pp. Wydawnictwo Universitatis Mariae Curie-Sklodowska; Lublin.

Terpiłowski, S., Zieliński, T., Kusiak, J., Pidek, I.A., Czubla, P., Hrynowiecka, A., Godlewska, A., Zieliński, P. and Małek, M. 2014. How to resolve Pleistocene stratigraphic problems by different methods? A case study from eastern Poland. *Geological Quarterly*, **58** (2), 235–250.

Terpiłowski, S., Zieliński, T., Mroczek, P., Zieliński, P., Czubla, P. and Fedorowicz, S. 2021. New evidence for the rank of the Wartanian cold period (the Pleistocene, MIS 6): a case study from E Poland. *Annales Societatis Geologorum Poloniae*, **91**, 327–345.

Valde-Nowak, P. and Łanczont, M. 2021. State of the art. overview of the Loess Palaeolithic of Poland. *Journal of Quaternary Science*, **36** (8), 1341–1352.

Winter, H. 2006. Ekspertyza wyników analizy pyłkowej próbek z Przytulina i Małej Bystrzycy, arkusz Adamów (639) SMGP 1: 50 000. NAG PIG-PIB; Warszawa.

Winter, H. 2008. Some remarks on the Mazovian Interglacial in Eastern Poland. *Przegląd Geologiczny*, **56** (3), 225–231. [In Polish with English summary]

Winter, H. 2009. Zapis palinologiczny mazowieckiej sukcesji pyłkowej w osadach z Przytulina. In: Żarski, M. and Lisicki, S. (Eds), Strefa marginalna lądolodu zlodowacenia Warty i pojezierza plejstoceńskie na południowym Podlasiu. XVI Konferencja Stratygrafia Plejstocenu Polski. Zimna Woda k. Łukowa, 31.08–4.09.2009, 195–198. Państwowy Instytut Geologiczny; Warszawa.

Wodyk, K. 2004a. Szczegółowa Mapa Geologiczna Polski 1:50 000, arkusz Skórzec (564). NAG PIG-PIB; Warszawa.

Wodyk, K. 2004b. Objaśnienia do Szczegółowej Mapy Geologicznej Polski 1:50 000, arkusz Skórzec (564). NAG PIG-PIB; Warszawa.

Velichkevich, F.J., Deruogo, G., Zernitskaya, V., Ilkevich, L., Levitskaya, L., Litviniuk, L., Matveyev. A., Nazarov, V., Sanko, F., Rylova, T., Khursevich, G. and Yakubovskaya, T. 2001. Quaternary of Belarus. In: Makhnach, A., Garetski, R. and Matveyev, A. (Eds), Geology of Belarus, 325–386. Institute of Belarus, Institute of Geological Sciences; Minsk.

Zaborski, B. 1927. Studia nad morfologią dyluwium Podlasia i terenów sąsiednich. *Przegląd Geograficzny*, **7**, 1–4. [In Polish with French summary].

Żarski, M. 2004. Strefa marginalna lądolodu zlodowacenia Warty na Wysoczyźnie Żelechowskiej. In: Harasimiuk, M. and Terpiłowski, S. (Eds), Zlodowacenie Warty w Polsce, 113–123. Wydawnictwo Universitatis Mariae Curie-Sklodowska; Lublin.

Żarski, M. 2006. Problem zasięgu zlodowacenia zlodowacenia Odry na Nizinie Południowopodlaskiej. In: Morawski, W. (Ed.), Materiały XIII Konferencja Stratygrafia Plejstocenu Polski, Plejstocen południowej Warmii i zachodnich Mazur na tle struktur podłoża, 149. Państwowy Instytut Geologiczny-Państwowy Instytut Badawczy; Warszawa.

Żarski, M. 2007a. Szczegółowa Mapa Geologiczna Polski w skali 1: 50 000, arkusz Okrzeja (638). NAG PIG-PIB; Warszawa.

Żarski, M. 2007b. Objaśnienia do Szczegółowej Mapy Geologicznej Polski w skali 1: 50 000, arkusz Okrzeja (638). NAG PIG-PIB; Warszawa.

Żarski, M. 2008. Objaśnienia do Szczegółowej Mapy Geologicznej Polski w skali 1: 50 000, arkusz Adamów (639). NAG PIG-PIB; Warszawa.

Żarski, M. 2009. Szczegółowa Mapa Geologiczna Polski w skali 1: 50 000, arkusz Adamów (639). NAG PIG-PIB; Warszawa.

Żarski, M. 2012a. Szczegółowa Mapa Geologiczna Polski w skali 1: 50 000, arkusz Żelechów (637). NAG PIG-PIB; Warszawa.

Żarski M. 2012b. Objaśnienia do Szczegółowej Mapy Geologicznej Polski w skali 1: 50 000, arkusz Żelechów (637). NAG PIG-PIB; Warszawa.

Żarski, M., Nita, M. and Winter, H. 2005a. Nowe stanowiska interglacjalne w rejonie dolin Wilgi i Okrzejki na Wysoczyźnie Żelechowskiej (Polska południowo-wschodnia). *Przegląd Geologiczny*, **53** (2), 137–144.

Żarski, M. and Krupiński, K. 2005b. Pojezierze plejstoceńskie południowo-wschodniej części Niziny Południowopodlaskiej. Materiały II Konferencji Paleobotaniki Czwartorzędu Okuninka, 36–38. NAG PIG-PIB; Warszawa.

Żarski, M., Małek, M. and Albrycht, A. 2009a. Plejstocen południowego Podlasia. In: Żarski, M. and Lisicki, S. (Eds), Strefa marginalna lądolodu zlodowacenia Warty i pojezierza plejstoceńskie na południowym Podlasiu. XVI Konferencja Stratygrafia Plejstocenu Polski. Zimna Woda

k. Łukowa, 31.08–4.09.2009, 13–19. Państwowy Instytut Geologiczny; Warszawa.

Żarski, M., Winter, H., Marcinkowski, B. and Wyszomierski, M. 2009b. Sytuacja geologiczna osadów interglacjału mazowieckiego w Przytulinie. In: Żarski, M. and Lisicki, S. (Eds), Strefa marginalna lądolodu zlodowacenia Warty i pojezierza plejstoceńskie na południowym Podlasiu. XVI Konferencja Stratygrafia Plejstocenu Polski. Zimna Woda k. Łukowa, 31.08–4.09.2009, 189–194. Państwowy Instytut Geologiczny; Warszawa.

Żarski, M., Marcinkowski, B. and Wyszomierski, M. 2009c. Sytuacja geologiczna jeziornych osadów interglacjału mazowieckiego w Hermanowie. In: Żarski, M. and Lisicki, S. (Eds), Strefa marginalna lądolodu zlodowacenia Warty i pojezierza plejstoceńskie na południowym Podlasiu. XVI Konferencja Stratygrafia Plejstocenu Polski. Zimna Woda k. Łukowa, 31.08–4.09.2009, 180–184. Państwowy Instytut Geologiczny; Warszawa.

Żarski, M. and Kucharska, M. 2019. Objaśnienia do Mapy geologicznej Polski w skali 1: 200 000, arkusz Siedlce. NAG PIG-PIB; Warszawa.

Żarski, M., Pochocka-Szwarc, K., Hrynowiecka, A., Marks, L., Bahdasarau, M., Bogucki, A. and Zalesky, I. 2023. Stratygrafia i paleogeografia czwartorzędu. In: Marks, L. (Ed.), Geological Map of Polish-Belarusian-Ukrainian Border Area. Włodawa Region. Explanatory text, 23–57 [In Polish with English summary]. Państwowy Instytut Geologiczny-Państwowy Instytut Badawczy; Warszawa.

*Manuscript submitted: 21$^{st}$ January 2024*
*Revised version accepted: 11$^{th}$ June 2024*