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A new interpretation of the geology of the Włodawa Heights (Western Polesie, eastern Poland)

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The Włodawa Heights are a morphological elevation composed of Pleistocene deposits located in Western Polesie (eastern Poland). Analysis of the geology of this area based on the type localities of the Mazovian (Holsteinian, MIS 11c) Interglacial allowed the conclusion that it was covered by only two ice-sheets, representing the Sanian 1 and Sanian 2 glaciations respectively (Glacial B, MIS 16 and Elsterian, MIS 12). The elevation was located beyond the range of the Odranian (Saalian, MIS 6) Glaciation. Two horizons of glacial till correlated with the Sanian 1 and Sanian 2 glaciations, and separated by biogenic deposits of the Ferdynandovian (Cromerian III-IV, MIS 13-15) Interglacial, have been distinguished within this elevation in Sosnowica. Deposits of the Sanian 2 (Elsterian, MIS 12) Glaciation are overlain by lacustrine deposits of the Mazovian (Holsteinian, MIS 11c) Interglacial, documented by palaeobotanical studies in sites occurring close to the terrain surface. The sites include: Dobropol B, Suszno (Cegielnia and Scarp), Włodawa Cegielnia, Wyryki, Korolówka, and Ignaców. The lacustrine deposits document a vegetational succession typical of the Mazovian Interglacial. Glacial deposits have not been documented above; in turn, these deposits are overlain by lacustrine deposits of the Liviecian (Fuhne, MIS 10), niveolacustrine deposits of the Odranian (Saalian, MIS 6) and, most commonly, of the Vistulian (Weichselian, MIS 2-5d) glaciations. At most sites, deposits of the Mazovian Interglacial and those overlying them infill palaeotroughs. The Bug River valley was initially also a subglacial trough, which was filled with fluvial and biogenic sediments during the Mazovian (Holsteinian, MIS 11c) Interglacial. Renewal of Bug runoff in the study area took place during the Vistulian (Weichselian, MIS 2-5d) Glaciation. As a megaform, the Włodawa Heights represent an outlier formed due to the erosional activity of fluvioglacial waters during the recession of the Sanian 2 ice-sheet. The form is not an elevation of Cretaceous rocks, because the top of Cretaceous strata to the south of Włodawa Heights in the Łęczna-Włodawa Lakeland is located much higher. In the northern part of the Włodawa Heights, minor, NE–SW oriented faults with a throw of 20–30 m, as well as faults with a transverse orientation, have been observed in the Cretaceous rocks. Fracturing of the rock massif, including the development of minor faults, took place during the Alpine deformation events. The geological structure of the Włodawa Heights also does not correspond to the Variscan structural plan, as the area is located within the Włodawa Depression, filled with thick Paleozoic strata and overlain by a succession of Mesozoic rocks which do not display discontinuous deformation.

Key words: Włodawa Heights, Western Polesie, Elsterian, Mazovian (Holsteinian) Interglacial, Maastrichtian.

INTRODUCTION

The Włodawa Heights represent a parallel-sided morphological elevation, which is a mesoregion of Western Polesie (Richling et al., 2021). To the north, they bound the Sosnowica Depression, and to the south the Łęczna-Włodawa Lakeland

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(Fig. 1). The most recent studies performed in Western Polesie have revised concepts of the geology of the terrain and demonstrated that the last ice-sheet that covered the study area belonged to the Sanian 2 (Elsterian, MIS 12) Glaciation (Żarski et al., 2024; Pochocka-Szwarc et al., 2024, 2025a, b), and not the Odranian (Saalian, MIS 6) Glaciation, as considered previously (Buraczyński et al., 1984; Buraczyński, 1986; Dolecki et al., 1991, 1994; Dolecki and Wojtanowicz 1992; Wojtanowicz, 1993, 1994a, b; Lindner, 1996).

This stratigraphy of the deposits building the surface of the Włodawa Heights has been recently shown on regional maps at 1:250,000 scale (Pochocka-Szwarc and Żarski, 2023; Żarski et al., 2023) and 1:50,000 scale (Pochocka-Szwarc, 2023a, b, c, d; Kucharska, 2023a, b). The idea that Western Polesie was covered by the ice-sheet of the Odranian (Saalian, MIS 6) Glaciation is almost 100 years old, reaches back to the works of Sawicki (1922) and Zaborski (1927), and has persisted until present (e.g., Buraczyński and Wojtanowicz, 1980/1981; Lindner et al., 1985, 2004). This study presents a new concept of the Pleistocene structure of the Włodawa Heights, which is in accordance with the most recent studies of the area (Żarski et al., 2009, 2024; Pochocka-Szwarc et al., 2021, 2024, 2025a, b). The basis for this new concept is the geological and palaeobotanical analysis of sites with deposits of the Mazovian (Holsteinian, MIS 11 c) Interglacial, coupled with the reconstruction of the mostly Cretaceous basement to the Quaternary deposits.

REVIEW OF PREVIOUS RESEARCH

The history of studies on the Quaternary deposits and their Cretaceous and Paleogene-Neogene basement in Polesie within the boundaries of Poland, Ukraine and Belarus reaches back to the early 20th century. The investigations included Volhynian Polesie located to the south and south-east of the study area. Tutkovsky (1901, 1904) described evidence of the former presence of an ice-sheet in that area based on elevations representing frontal moraines and eskers, as well as erratic boulders of Scandinavian origin. Gagel and Korn (1908) and Gagel (1922) documented one horizon of glacial till on the terrain surface, which they correlated with an older glaciation but did not determine its exact age [present knowledge suggests that this glaciation may be correlated with the Sanian 2 (Elsterian) Glaciation]. According to this concept, the ice-sheet must have also covered the Włodawa Heights. According to Sawicki (1922), Polesie was covered by the ice-sheet of the Middle-Polish Glaciation, at present correlated with the Odranian (Saalian) Glaciation. Of crucial significance are the works of Lilpop (1925a, b), who documented peats with macroremains of plants typical of a warmer climate in natural exposures along the lower Bug scarp observed in Włodawa and nearby Koszary (presently in Ukraine). He also suggested that they represent interglacial sediments separating glaciations L3 and L4; the first corresponds to the Sanian 2 (Elsterian) Glaciation and the second to the Odranian (Saalian) Glaciation.

A key study for the recognition of the Pleistocene geology and palaeogeography of the Włodawa Heights and the entire Western Polesie was by Zaborski (1927), according to whom Polesie was covered by the ice-sheet of the Middle-Polish Glaciation [presently correlated with the Odranian (Saalian) Glaciation; Table 1]. On the Włodawa Heights, that author distinguished a series of elevations attributed to frontal moraines, e.g., in Górki, Pieszowola, Ludwiczyn, Marianka, Brus Nowy, and Różanka, as well as accompanying units of glacial till and fluvioglacial sand. The concept of Zaborski (1927) explaining the geology of Western Polesie, including the Włodawa Heights, lasted till the 2020s.

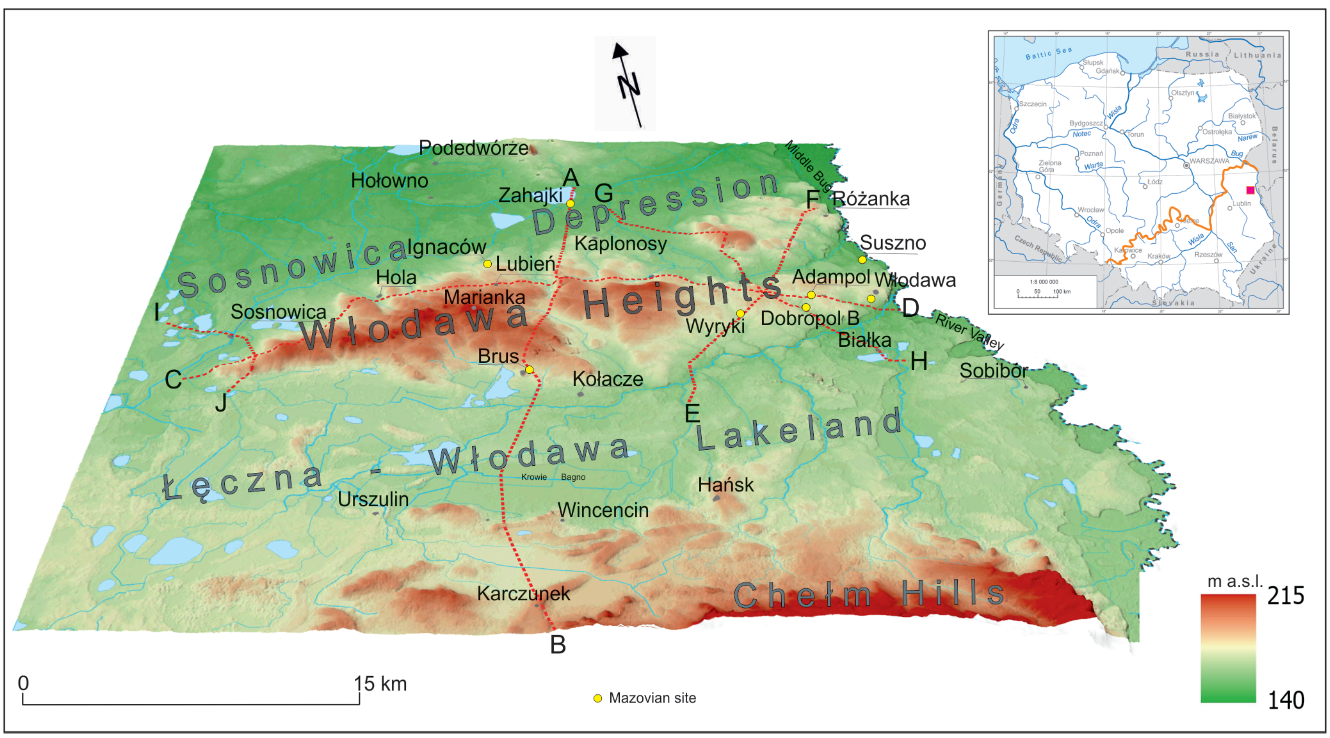

Fig. 1. Location of the study area with the position of the geological cross-sections described further below

Table 1

Chronostratigraphic correlation of the Middle and Upper Pleistocene in northwestern Europe (Litt et al., 2007; Head and Gibbard, 2015), southeastern Poland (Lindner et al., 2006, modified; Marks et al., 2016, modified), Belarus (Velichkevich et al., 2001), Ukraine (Lindner et al., 2004, 2006, 2007), and marine isotope stages (MIS); modified after Pochocka-Szwarc et al. (2024, 2025a)

Age [ka BP]	Stratigraphy		Northwestern Europe	Southeastern Poland	Belarus	Ukraine	MIS
11.7	Holocene	Holocene	Holocene	Holocene	Holocene	1	
130	Upper Pleistocene	Weichselian	Vistulian	Poozierian	Valday	2-5d	
		Eemian	Eemian	Muravian	Pryluky	5e	
780	Middle Pleistocene	Saalian Complex	Warthe + Drenthe	Odranian (Odranian+ Warthanian)	Pripyatian (Dnieperian+Sozhian)	Dnieperian2	6
			Schöningen	Lublinan	Shklovian	Kaydakay	7
			?	Krznanian *	?	Dnieperian1	8
			Dömitz-Wacken	Zbójnian	Smolenskian	Potagylivka	9
			Fuhne	Liviecian *	?	Orelian	11b-10
		Holsteinian	Holsteinian	Mazovian	Alexandrian	Likhvinian	11c
		Cromerian Complex	Elsterian	Sanian 2	Berezinian	Okaan	12
			Cromerian IV	Ferdynandovian	Belovezhian	Lubenian	13
			Glacial C				14
			Cromerian III				15
			Glacial B	Sanian 1	Narevian	Sulian	16
			Cromerian II	Podlasian	Różan	Martonoshian	17
			Glacial A				18
			Cromerian I				19

* – area not covered by ice-sheets

According to Rühle (1936, 1937), Polesie was covered by the Scandinavian ice-sheet twice, during the South-Polish Glaciations (presently the Elsterian Complex). He later revised this view, based on the presence of deposits representing the Mazovian (Holsteinian) Interglacial in Stare Koszary near Kovel (Ukraine), which according to him were located between glacial tills of the South-Polish Glaciation (Sanian 2, Elsterian) and the Middle-Polish Glaciation (Odranian, Saalian). The geological context of peats exposed in the Bug valley scarp, as well as in the nearby brickyard in Suszno (within the Włodawa Heights) was described by Trembaczowski (1957), and Mojski and Trembaczowski (1961).

According to these authors, peats separate glacial deposits of the South-Polish (Sanian 2, Elsterian) and Middle-Polish (Odranian, Saalian) glaciations. Based on palynological analyses, these peats were correlated with the Mazovian Interglacial (Holsteinian) (Stachurska, 1957, 1961). Trembaczowski (1957, 1963, 1968) described the geology of Pleistocene deposits in the western part of the Włodawa Heights near Włodawa. The interglacial sites recognized in Polesie (in the areas of both Poland and Ukraine) until the 1970s was reviewed by Karaszewski and Rühle (1976).

A large contribution to the recognition of the geology of the Włodawa Heights were mapping surveys for the Detailed Geological Map of Poland at the scale of 1:50,000 (Trembaczowski, 1965, 1968; Buraczyński and Wojtanowicz, 1981, 1982; Dolecki et al., 1987, 1990; Marszałek, 2000, 2001; Żarski and Morawski, 2018, 2019). These resulted in a number of publications describing the geology of the Pleistocene strata of the Włodawa Heights (Buraczyński and Wojtanowicz, 1980/1981; Buraczyński et al., 1984; Buraczyński, 1986; Dolecki et al., 1987, 1990). These suggested that Western Polesie was covered by the Odranian (Saalian) ice-sheet. The authors cited stated that the Włodawa Heights are composed of glacial, ice-dammed and fluvioglacial deposits of the South-Polish and Odranian glaciations. A similar concept of the structure of Pleistocene deposits of the Włodawa Heights was proposed in a more recent paper by Dobrowolski and Chabudziński (2021). Of crucial significance are studies devoted to the stratigraphy and palaeogeography of the area (Lindner et al., 1991, 2004, 2006, 2007; Lindner and Szymanek, 2018; Marks and Pavlovskaja, 2006; Rychel et al., 2021; Orłowska et al., 2025), which describe the geology of Pleistocene deposits in Southern Podlasie. The Pleistocene stratigraphy of Polesie is based on type sites with fossil lacustrine deposits representing the Ferdynandovian Interglacial (Cromerian III–IV; Table 1), documented in Sosnowica, located beneath the western slopes of the Włodawa Heights (Dolecki et al., 1991; Janczyk-Kopikowa, 1991), as well as in Ferdynandów, Łuków, and Zdany in Podlasie (Janczyk-Kopikowa et al., 1981; Rzechowski, 1996; Pidek, 2003, 2015; Pidek and Małek, 2010; Pidek et al., 2015; Stachowicz-Rybka et al., 2017).

Of highest importance for the recognition of the geology and stratigraphy of Western Polesie are sites with lacustrine deposits from the Mazovian Interglacial (Holsteinian, MIS-11c; Table 1) occurring almost directly on the surface of the Włodawa Heights (Pidek, 2003; Hrynowiecka et al., 2014; Hrynowiecka and Pidek, 2017; Pochocka-Szwarc et al., 2021, 2024, 2025a;

Żarski et al., 2024). They document successions representing the Mazovian Interglacial and the accompanying coolings of the Late Elsterian Glacial and the Early Liviecian Glaciation (Fuhne, MIS 11ba-10) recorded in lacustrine and biogenic deposits. There are no glacial deposits lying above interglacial deposits at these sites. In turn, the overlying horizons represent clastic deposits of the Vistulian and Holocene. These observations lead to the conclusion that the last Pleistocene ice-sheet that covered this part of Poland belonged to the Sanian 2 Glaciation (Elsterian; Marks, 2023a). Such a stratigraphic interpretation was assumed in the most recent mapping reports devoted to Pleistocene deposits of Western Polesie (Pochocka-Szwarc, 2023a, b, c, d; Kucharska, 2023a, b; Pochocka-Szwarc and Żarski, 2023).

Important palaeogeographic conclusions can be drawn from the geological position of the lacustrine deposits of the Mazovian (Holsteinian) Interglacial in documented sites located to the north of the study area in Southern Podlasie (Lindner, 1988; Krupiński, 1988; Lindner et al., 1990, 1991; Albrycht et al., 1995; Lindner and Wyrwicki, 1996; Lindner and Marciniak, 1997, 1998; Lindner and Marks, 1999; Krupiński, 2000; Nitychoruk, 2000; Nitychoruk et al., 2005; Szymanek et al., 2005; Małek and Pidek, 2007; Pidek et al., 2011; Szymanek, 2011, 2012, 2013, 2014; Terpiłowski et al., 2014, 2021; Marks et al., 2018; Hrynowiecka et al., 2019; Górecki et al., 2022; Żarski et al., 2024), where lacustrine deposits of the Mazovian Interglacial that are not overlain by glacial deposits occur almost directly at the surface. This suggests that the area was not covered by an ice-sheet after the Sanian 2 (Elsterian) Glaciation.

STUDY AREA

The sites described are located on the Włodawa Heights, a distinct physical-geographic unit within Western Polesie (Fig. 1). This parallel-sided morphological structure extends for 34 km from Sosnowica in the west to Włodawa in the east. The maximum width of the Włodawa Heights within the Polish territory is 23 km, averaging ~12 km. The boundary Bug River cuts the elevation, which continues to the east into Ukraine and Belarus.

The highest point of the Włodawa Heights is located on its western part, i.e. near Marianka. This is a frontal moraine with an elevation of 212.7 m a.s.l. (Pochocka-Szwarc, 2023b). In general, the surface of the Włodawa Heights lies between 170–190 m a.s.l. To the north, i.e. from the Sosnowica Depression, the height differences are in the range of 20–40 m, whereas to the south (from the Łęczna-Włodawa Lakeland), the gently sloping slopes of this landform rise to 20–30 m above the Łęczna-Włodawa Lakeland. The height differences rapidly decrease towards the east of the heights, reaching 17–20 m. The topmost parts of the heights are characterized by flat surfaces and their slopes are gently inclined. The Włodawa Heights are incised by three valleys, clearly distinguishable in the present-day morphology, which are probably transformed glacial troughs (Fig. 1). The heights represent a morphological elevation composed mainly of Pleistocene deposits. The western and central parts of their surface are built of glacial tills and glacial sands and gravels, and the eastern parts mainly of fluvioglacial sands and gravels. In the western part directly below the surface occur Cretaceous limestones, as well as marine and terrestrial strata representing the Paleogene and Neogene (Pochocka-Szwarc, 2023b; Pochocka-Szwarc and Żarski, 2023).

GEOLOGICAL SETTING

STRUCTURAL PLAN

The Włodawa Heights are situated on the western slope of the East-European Platform within a Paleoproterozoic tectonic suture zone, which is expressed by the presence of diverse crystalline rocks of different ages (Krzemińska et al., 2017; Mazur et al., 2017). A characteristic feature of the region is the presence of crystalline rocks occurring at different depths, from 430 to over 1800 m. This is the effect of numerous faults, which cut into the crystalline basement, resulting in a platform-type geological structure (Żelichowski, 1972, 1974; Mazur et al., 2017; Krzemińska et al., 2017). The Włodawa Heights are situated within a Paleozoic structure known as the Włodawa Depression (Fig. 2), separated in the north from the Łuków Edge by the Hanna Fault (located several kilometres from the Włodawa Heights) and in the south from the Kumów Edge by the Święcica Fault (Żelichowski, 1972, 1974). The displacement of the top of the crystalline rocks (Łuków Edge vs. Włodawa Depression) along these NE–SW oriented faults is almost 1500 m

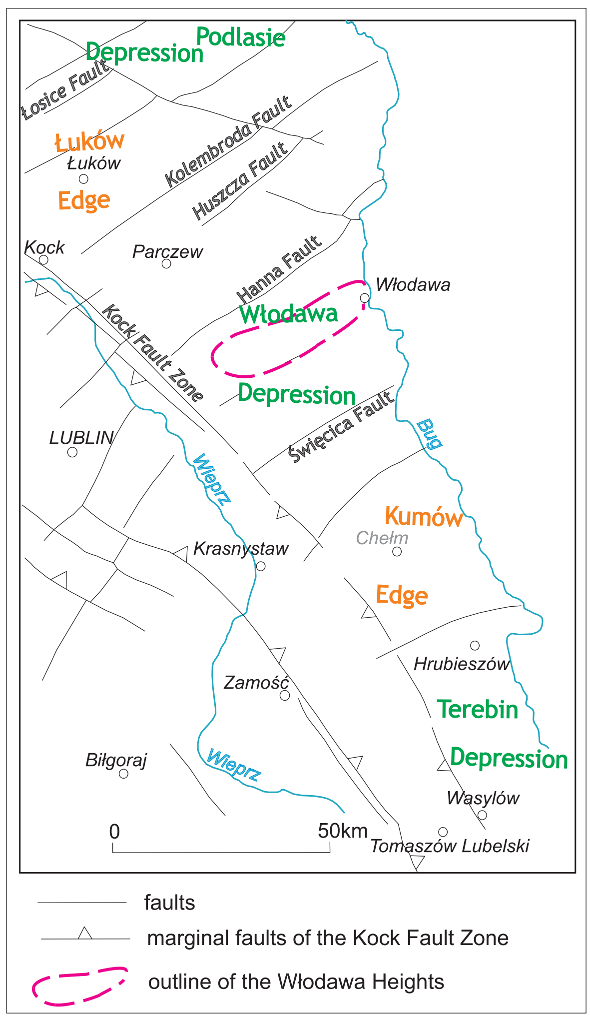

Fig. 2. Sketch-map of structural units in the basement of southern Podlasie and Polesie, after Żelichowski (1974), modified

(the top of the crystalline rocks in the Holeszów IG 1 borehole is at a depth of 430 m, and in Kaplonosy IG 1 borehole it is at 1881 m; Areń, 1974; Krzemińska et al., 2017). This geological structure favoured the accumulation of large thicknesses of Paleozoic strata. The main structural plan was shaped during the Bretonian and Asturian phases of the Variscan Orogeny (Żelichowski, 1972, 1984; Narkiewicz, 2003; Krzywiec, 2007; Narkiewicz et al., 2007). The main faults separating the Łuków Edge and the Włodawa Depression into lower-rank structural units are accompanied by similarly oriented parallel faults characterised by small displacement of the top of crystalline rocks (Żelichowski, 1974, 1984).

In the study area, crystalline and Paleozoic rocks are overlain by Mesozoic strata. Terrigenous and marine deposits representing the Middle and Upper Jurassic overlap Carboniferous rocks. Lower and Upper Cretaceous strata occur commonly, forming the basement for the localized occurrences of Paleogene strata. The Cretaceous rocks are almost flat lying, as they were not subject to folding during the Alpine deformation and are affected by very few faults (Pożaryski, 1974). A network of vertical joint fractures formed due to stress caused by the uplift of Roztocze, located ~100 km to the south of the study area, was most probably created at that time (Henkiel, 1984; Harasimiuk and Henkiel, 1984; Buraczyński, 2013). The tectonic activity of Roztocze took place during the Laramian Phase of the Alpine Orogeny, i.e. in the Neogene and Early Pleistocene (Harasimiuk and Henkiel, 1984). Dobrowolski and Harasimiuk (2002) distinguished three phases of neotectonic activity in Polesie: a late Paleogene one lasting from the Late Eocene to the Middle Oligocene; an Early Neogene one lasting from the Late Oligocene to the Early Pliocene, and a Late Neogene – Quaternary one.

BASEMENT TO THE QUATERNARY DEPOSITS OF THE WŁODAWA HEIGHTS

This basement is composed of marine strata representing the uppermost stage of the Upper Cretaceous, i.e. the Maastrichtian, as well as the Paleogene (Eocene and Oligocene) and Neogene (Miocene). Maastrichtian carbonate rocks include chalk, marls and infrequent marly limestones. They are documented in numerous wells, and their stratigraphic position has been determined based on foraminifera assemblages, including index taxa such as: *Gavelinella gankinoensis* (Neckaja) and *Gavelinella danica* (Brotzen) (Buraczyński and Wojtanowicz, 1982; Gawor-Biedowa, 1992). Exposures of Maastrichtian strata at the surface or beneath a thin cover of Cenozoic deposits are common to the south of the Włodawa Heights in the Łęczna-Włodawa Lakeland.

The Maastrichtian structural pattern, as well as the lithology and palaeomorphology of the Cretaceous top surface (Fig. 3) had a decisive role for the development of Paleogene, Neogene and Pleistocene strata, as well as the present-day relief of Western Polesie (Żarski et al., 2023; Żarski and Pochocka-Szwarc, 2025). The geological context of the upper Maastrichtian strata is well-illustrated in cross-sections cutting the Włodawa Heights (Fig. 4), constructed on the basis of borehole data. The top of the Cretaceous rises towards the south and south-east (Fig. 3). In the Sosnowica Depression the top of the Cretaceous lies at an elevation of 100–120 m a.s.l., below the Włodawa Heights it lies at 130–160 m a.s.l., whereas farther to the south, in Łęczna-Włodawa Lakeland, it lies at elevations in the range of 160 to 190 m a.s.l., mostly occurring at the surface.

A hypothesis expressed by numerous scientists (e.g., Trembaczowski, 1968; Buraczyński and Wojtanowicz, 1980; Dobrowolski and Chabudziński, 2021) that the Włodawa Heights represent an elevation composed of Cretaceous rocks does not find confirmation (Fig. 3), because to the south of the heights, the top of the Maastrichtian rocks is located much higher, locally reaching the surface (Łęczna-Włodawa Lakeland). Only the northern margin of the Włodawa Heights is probably of tectonic origin (Figs. 3 and 4A), as fault zones uplifting Maastrichtian rocks from 100–120 m a.s.l. to 130–160 m a.s.l. have been documented here (Figs. 3 and 4B). The faults are NE–SW, NW–SE and N–S oriented (Fig. 3). The throw on the Cretaceous rocks is, however, rather small, reaching 20 to 30 m. Furthermore, the top of the Maastrichtian in the Włodawa Heights is variable, resulting in troughs (probably of tectonic origin) and elevations (Figs. 3 and 4). The height differences in the Cretaceous surface reach up to 30 m, as shown by the sub-parallel cross-section (Fig. 4A, E). Larger troughs of tectonic origin affecting the Maastrichtian strata occur in the vicinity of Turno and to the east of Adampol (Fig. 4B). The central part of the Włodawa Heights lies in a wide depression, in which the top of the Cretaceous is situated at an elevation of ~140 m a.s.l. This is also the part of the heights where the terrain surface is located at the highest level, i.e. ~190 m a.s.l. Elevations composed of Cretaceous deposits occur near Pasieka, Adampol and Suchawa (Fig. 4B–D). These cause the surface of the Cretaceous to take the form of a micro-horst-depression network. Moreover, fault and fracture zones favoured the development of later processes of chemical denudation within the Cretaceous carbonate rocks (palaeokarst in the Łęczna-Włodawa Lakeland; Maruszczak, 1966, 2001; Harasimiuk, 1975; Dobrowolski, 2006), as well as erosion during the Neogene and Pleistocene.

Beside Cretaceous rocks of marine origin, the sub-Quaternary basement of the Włodawa Heights is composed of quartz-glauconite sands, silts and clays attributed to the Middle and Upper Eocene and Lower Oligocene, and terrestrial deposits including silts, clays and quartz sands representing the Middle Miocene (Pochocka-Szwarc, 2023b, c). Middle and Upper Eocene strata occur in the Włodawa Heights in a patchy arrangement at variable elevations (Fig. 4A–C). They infill tectonic troughs, e.g. near Turno and Adampol (Fig. 4B) in the eastern part of the Włodawa Heights (Marszałek, 2000, 2001; Pochocka-Szwarc et al., 2025b). Near Włodawa, Eocene deposits occur locally, directly beneath the base of the Pleistocene. Near Turno (Fig. 4B), Eocene strata are overlain by Oligocene deposits (Dolecki et al., 1990; Pochocka-Szwarc, 2023b, c).

Paleogene strata are unconformably overlain by the Middle Miocene, developed in terrestrial facies (sands and silts with occasional interbeds of lignite; Pochocka-Szwarc et al., 2025b). The Middle Miocene deposits underlie the Quaternary succession of the Włodawa Heights in its northern (Fig. 4A–C) and central parts between Hola and Wyryki, as well as in the vicinity of Adampol and Wola Korolówka (Fig. 4B, C). They infill an ancient N–S oriented depression in the top-Cretaceous surface and probably of tectonic origin (Figs. 3 and 4B) .

QUATERNARY DEPOSITS OF THE WŁODAWA HEIGHTS

The Quaternary deposits composing the Włodawa Heights reach 30–50 m thick on average (Fig. 4A, B). In places they decrease to 10 m or less, e.g. near Wola Korolówka (Fig. 4C) or on

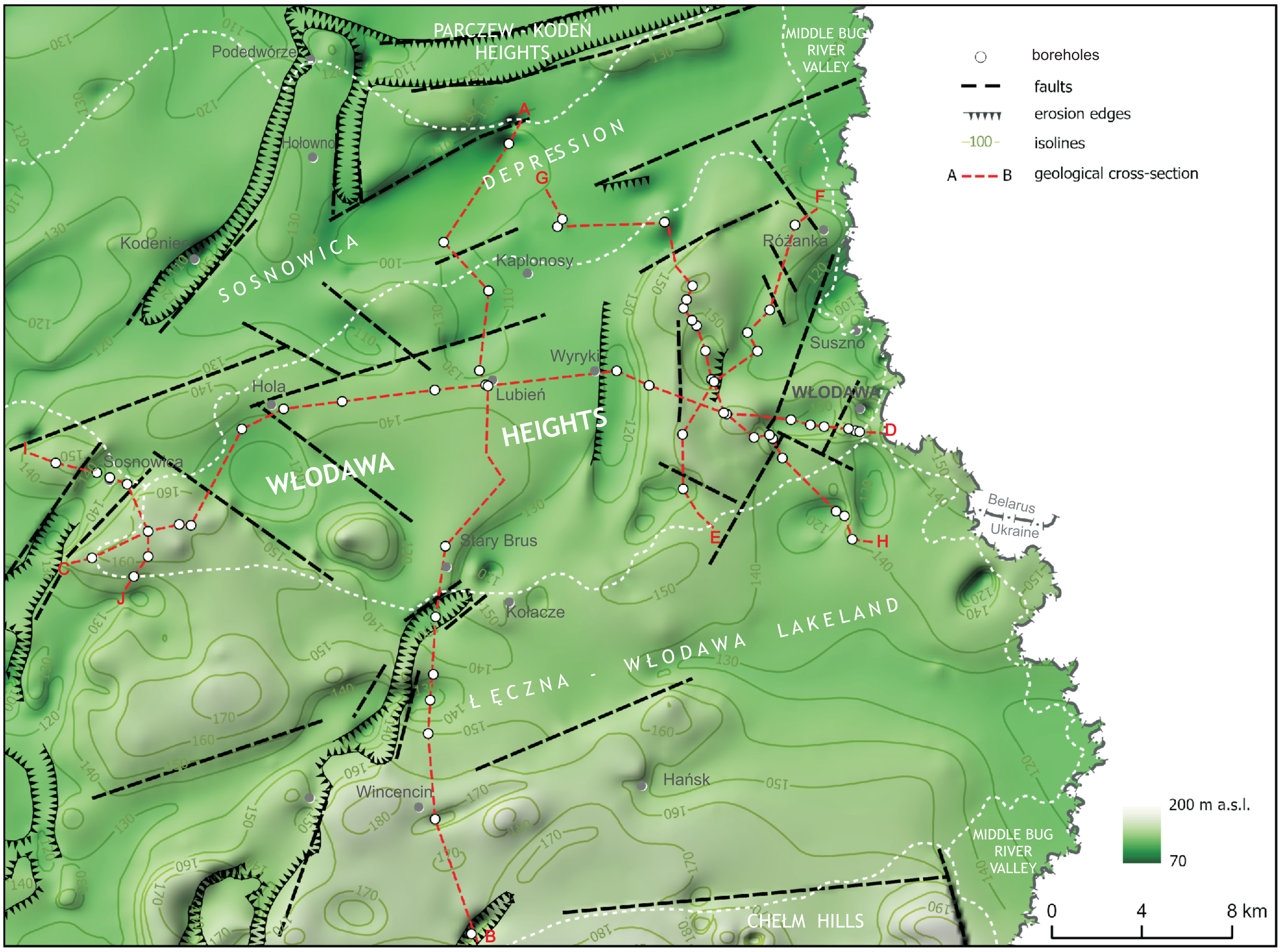

Fig. 3. Morphology of the top of the Cretaceous deposits (Maastrichtian chalk and marls)

the western slopes of the Włodawa Heights (Fig. 4E). Pleistocene deposits are represented by glacial tills (two horizons), fluvioglacial and ice-dammed deposits, as well as deposits of the Mazovian Interglacial (Żarski and Morawski, 2018, 2019; Pochocka-Szwarc, 2023a–d; Żarski et al., 2023; Żarski and Pochocka-Szwarc, 2025).

The South Polish Complex (Cromerian Complex, MIS 16-12) is composed of deposits representing the: Sanian 1 Glaciation (Glacial B, Narevian, MIS 16); Ferdynandovian Interglacial (Cromerian III, Belovezhian, MIS 15-13) and Sanian 2 Glaciation (Elsterian, Berezinian, MIS 12; Table 1; Litt et al., 2007; Marks et al., 2016, 2018; Marks, 2023a). They include deposits of various origin: glacial tills, sands and gravels; fluvioglacial sands and gravels; and ice-dammed silts and clays. Of key importance for the recognition of the geology of the Włodawa Heights is the Sosnowica borehole (Dolecki et al., 1991). This is located at the base of the Włodawa Heights on its western side (Fig. 4E). A succession of lacustrine deposits documenting the Ferdynandovian Interglacial (Cromerian III, MIS 15-13) was recognized in the succession (Janczyk-Kopikowa, 1987, 1991; Stachowicz-Rybka et al., 2017). Interglacial gyttja, peats and silts in the Sosnowica borehole were drilled in the depth interval 13.5–18.35 m. These deposits separate two horizons of glacial till, with the lower one correlated with the Sanian 1 Glaciation (MIS 16) and the upper with the Sanian 2 Glaciation (MIS 12) (Dolecki et al., 1990; Pochocka-Szwarc, 2023b).

In most boreholes located in the western and central parts of the Włodawa Heights there occur two glacial till horizons assigned to the Sanian 1 and Sanian 2 (MIS 16 and MIS 12) glaciations, and separated by fluvioglacial sands and gravels or ice-dammed silts and clays (Fig. 4A–C). In places, both glacial tills lie directly on one another (showing glaciotectonic deformation) or only one glacial till horizon is present; the latter is usually correlated with the Sanian 2 Glaciation (Fig. 4B).

In the western part of the Włodawa Heights near Pasieka and Zienki, glacial tills and the underlying thick (up to 20 m) succession of ice-dammed silts and clays display glaciotectonic deformation (Fig. 4B, E) with results from the morphological palaeomargin composed of Maastrichtian rocks which, during the ice-sheet advance, caused damming of ice and sediment. A similar process took place in Sarnaki (Albrycht, 2004, 2005) and in the vicinity of Uhruski Ridge (Chełm Hills) (Wyrwicka and Wyrwicki, 1986; Dobrowolski and Terpiłowski, 2006).

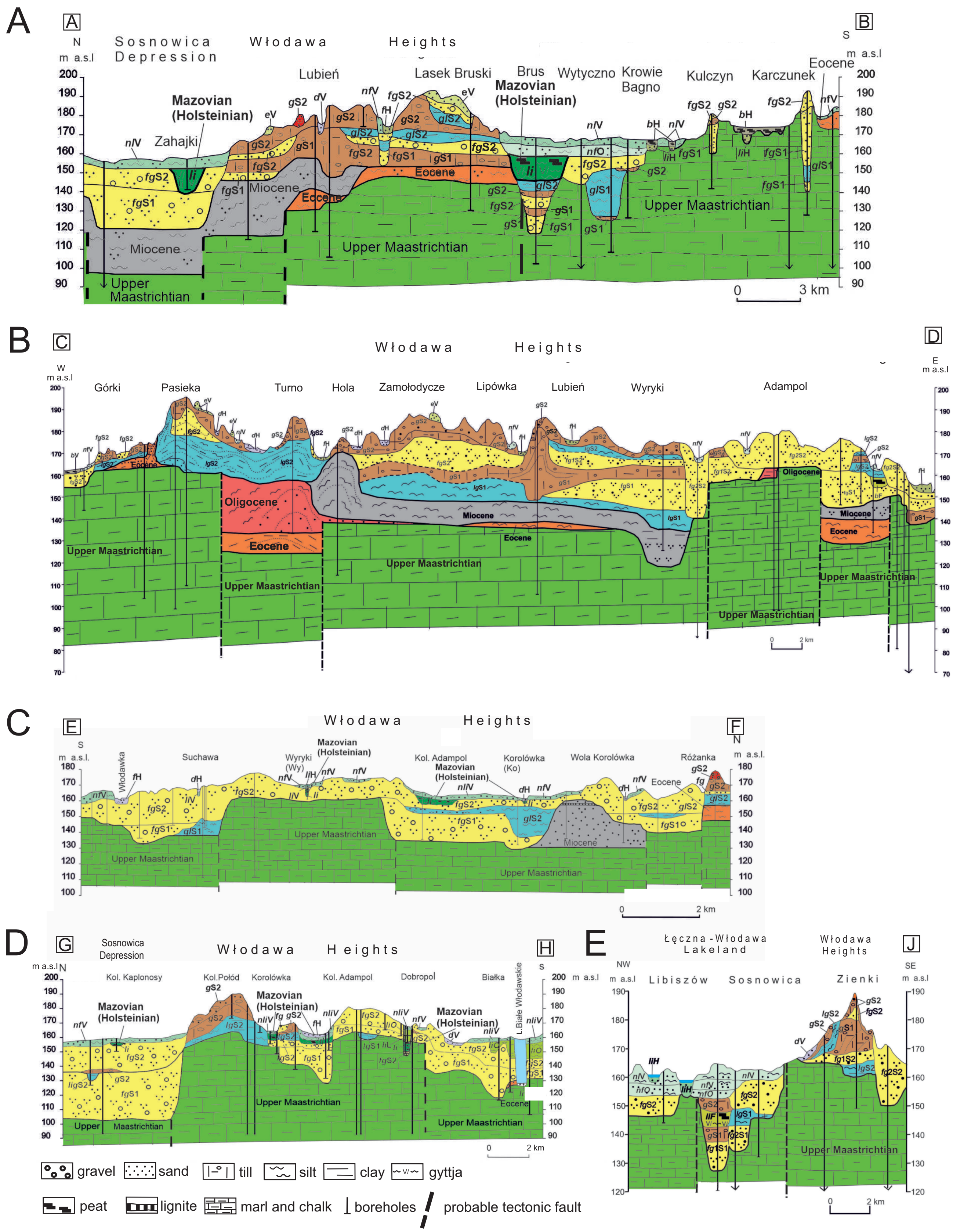

Fig. 4A–E – cross-sections through the Włodawa Heights, detailed location shown in Figure 1

Cross-section A–B – based on Pochocka-Szwarc and Żarski (2023); cross-section E–F – based on Żarski and Morawski (2019); cross-section G–H – based on Pochocka-Szwarc and Żarski (2023); cross-section I–J – based on Pochocka-Szwarc (2023a), modified; S1 – Sanian 1 (Glacial B, MIS 16), F – Ferdynandovian (Cromerian III, MIS 15), S2 – Sanian 2 (Elsterian, MIS 12), O – Odranian (Saalian, MIS 6), V – Vistulian (Weichselian, MIS 2), H – Holocene (MIS-1); b – biogenic, d – deluvial, e – aeolian, f – fluvial, fg – fluvoglacial, g – glacial, gl – glaciolacustrine, li – limnic, nf – niveofluvial, nli – niveolimnic

Moreover, a characteristic feature of the geological structure of the area is the fact that the eastern part of the Włodawa Heights is composed mainly of a thick (up to 30 m) succession of fluvioglacial deposits, and in places glacial sands and gravels representing the Sanian 1 (MIS 16) and Sanian 2 (MIS 12) glaciations (Fig. 4B, C). Fluvioglacial sands represent the stages of ice-sheet melting during the Sanian 1 and Sanian 2 glaciations. A characteristic feature of this part of the Włodawa Heights is the fact that it is devoid of glacial tills. Fluvioglacial sands and gravels occur both at elevations of Maastrichtian rocks (Wyryki, Adampol, Kol. Adampol) and in depressions on the top of the Cretaceous rocks (Korolówka, Wola Korolówka, Kol. Adampol, Adampol in the east).

The highest parts (over 200 m a.s.l.) of the Włodawa Heights represent denuded hills of frontal moraines composed of sands, gravels and strongly weathered boulders, characterized by a massive structure (Fig. 5). They are situated along the morphological axis of the Włodawa Heights, from Górki, Pieszowola, Marianka, Kamień, Zamołodycze, Horostyta to Lubień, where they form the highest morphological points of the landform (Żarski and Pochocka-Szwarc, 2025). Near Stawki and Różanka, frontal moraines represent the northernmost forms of glacial accumulation within the Włodawa Heights (Żarski and Morawski, 2018, 2019; Żarski et al., 2023; Pochocka-Szwarc and Żarski, 2023; Żarski and Pochocka-Szwarc, 2025; Orłowska et al., 2025).

Fig. 5. Exposure of massive gravels, sands and pebbles, forming the frontal moraine in Marianka of the Włodawa Heights

Photo M. Żarski

OVERVIEW OF SITES WITH DEPOSITS OF THE MAZOVIAN INTERGLACIAL ON THE WŁODAWA HEIGHTS

The locations (Fig. 6) and geological contexts of the biogenic and lacustrine deposits of the Mazovian Interglacial at the sites analysed are shown in cross-sections (Fig. 7) and lithological columns (Fig. 8).

Dobropol B. This site, with deposits of the Mazovian (Holsteinian) Interglacial in Dobropol, is situated at the edge of a brickpit located in the broadening of a dry valley running towards the Włodawka River valley (Fig. 6A). The site lies ~4 km to the south-west of Włodawa, in the southeastern part of the Włodawa Heights. The terrain surface is at an elevation of 165.5–167 m a.s.l. Deposits of the Mazovian Interglacial (silts and peats) reach 4.1 m in thickness and were documented by palaeobotanical analyses (Hrynowiecka et al., 2014). The overburden of these deposits is almost 12 m thick and composed of lacustrine deposits (silts, clays) of the Liviecian and Saalian glaciations, and an almost 3 m niveofluvial silt unit representing the Vistulian (Hrynowiecka et al., 2014). These deposits infill an ancient post-glacial trough from the Sanian 2 Glaciation, eroded into Upper Maastrichtian marls and chalk, as well as fluvioglacial deposits of the Sanian 2 Glaciation (Fig. 7A).

Suszno SU1-2015. This old brickpit in Suszno is situated ~2 km to the north of Włodawa. It is located in a small depression with a width of ~160 m, which is the beginning of a small dry valley, 400 m long, running to the east towards the Bug River (Fig. 6B). The bottom of the pit lies at an elevation of 159.5–160 m a.s.l., i.e. ~2 m below the terrain surface.

During mapping in 1997, a borehole was drilled in the brickyard; it documented lacustrine silts and peats of the Mazovian (Holsteinian) Interglacial (Obarska, 1996; Marszałek, 2000). Beneath the lacustrine deposits occur fluvial sands in the same stratigraphic position; their absolute OSL (Optically Stimulated Luminescence) age was determined at 367 ±89 ka BP (Kusiak, 1996 *fide* Marszałek, 2000). In 2015, a subsequent, fully cored borehole (SU1-15) was drilled, in which biogenic and lacustrine deposits were documented (Fig. 6B). Palaeobotanical analyses of these deposits allowed determination of a vegetational succession typical of the Mazovian (Holsteinian) Interglacial (Żarski et al., 2023). In the borehole, peat of the Mazovian Interglacial is 1.2 m thick. This are overlain by 0.8 m of peat from the Early Liviecian (Fuhne) Glaciation (Żarski et al., 2023). Below and above the biogenic succession occur fluvial sands, in places with peat intercalations. Above fluvial deposits correlated with the Early Liviecian occur sands and silts of the Odranian Glaciation with a thickness of 1.3 m, which in turn are overlain by niveolimnic clay and sandy silt, 5 m thick, representing the Vistulian (Żarski et al., 2023).

Suszno Scarp (SU-1961, SU-2015, SU-2019). Deposits attributed to the same palaeobasin are exposed in the Bug River scarp located 400 m from the old brickyard, to the north and south of the dry valley outlet (Trembaczowski, 1957; Stachurska, 1957, 1960, 1961; Mojski and Trembaczowski, 1961; Marszałek, 2000; Żarski et al., 2023; Fig. 6B).

The first description of **Suszno Scarp (SU-1961**) was given by Mojski and Trembaczowski (1961). Peats and peaty silts of the Mazovian Interglacial, 4.5 m thick, lie on fluvial sands of the same age. The biogenic deposits are overlain by almost 4 m of fine-grained deposits correlated with the Odranian (Saalian) and the Vistulian (Weichselian) glaciations. Palaeobotanical analyses of this succession were made by Stachurska (1961).

Suszno Scarp (SU-2015). This site is located slightly to the south of the dry valley outlet (Fig. 6B). The exposure was measured in 2015 and palynological analyses of the peats were

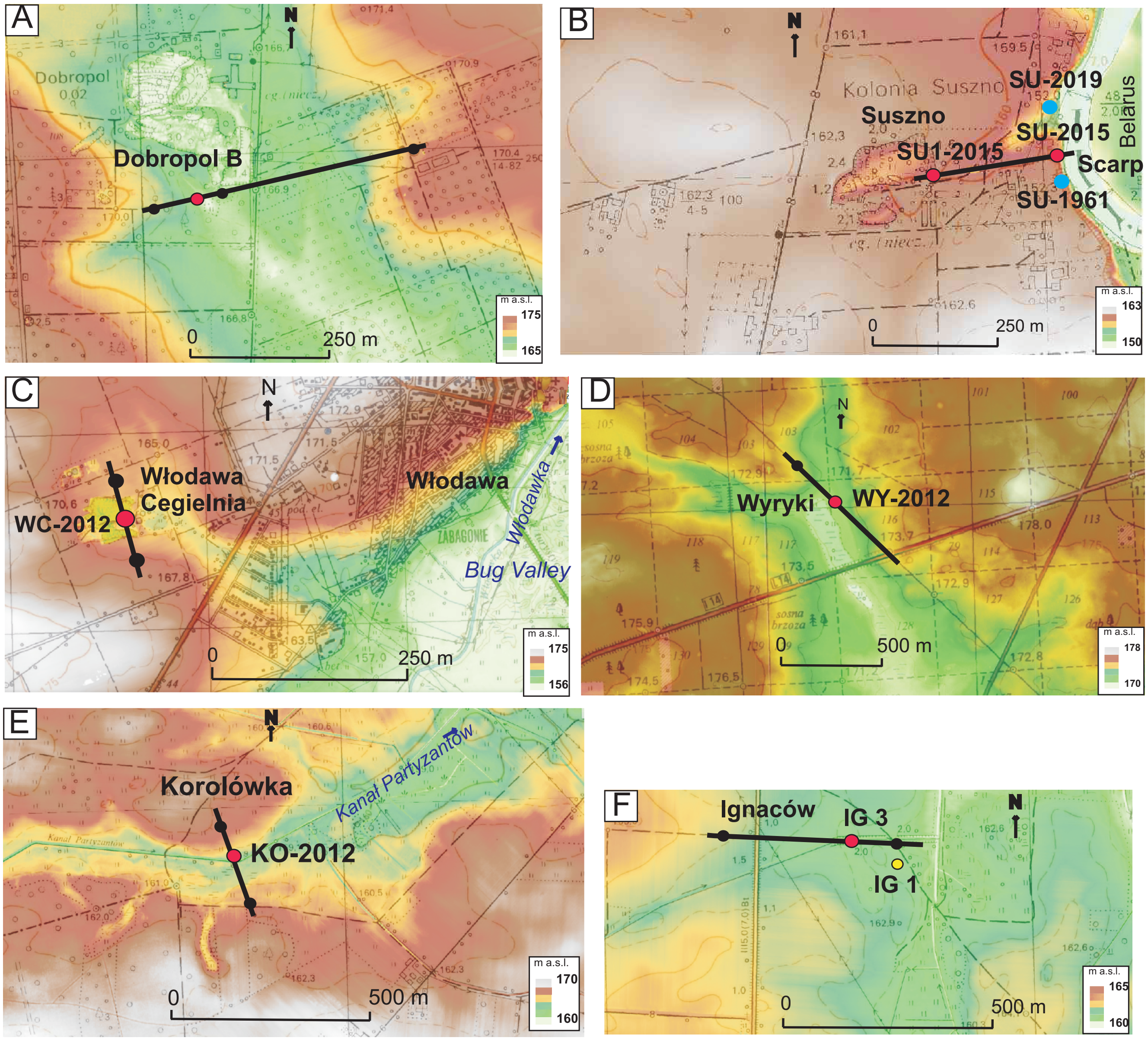

Fig. 6. Locations of sites with deposits of the Mazovian (Holsteinian) Interglacial on the Włodawa Heights

conducted (Żarski et al., 2023). Two sections were documented: Scarp 1 and Scarp 2 (Fig. 8). The biogenic series in Scarp 1 is ~2.2 m thick; its lower part (0.8 m) accumulated during the Mazovian (Holsteinian) Interglacial, and the upper part in the Liviecian (Fuhne) Glaciation (Żarski et al., 2023; Fig. 8). Below the biogenic succession occur fluvial sands of the Mazovian Interglacial, lying on ice-dammed silts of the Sanian 2 (Elsterian) Glaciation. The fluvial sands contain peat interbeds. Above the biogenic succession there are niveolimnic silts of the Vistulian almost 4 m thick, at the base of which is a thin sand layer from the Odranian (Saalian) Glaciation. The Scarp 2 section was located several metres to the north of the Scarp 1 section, directly above the Bug water level. It comprised 0.3 m of peats from the Mazovian (Holsteinian) Interglacial at the base, and 1.2 m of peats from the Liviecian (Fuhne) Glaciation in the middle and top of the section (k). As in the Scarp 1 section, this succession is overlain by Vistulian niveolimnic silts 4 m thick (Fig. 8).

Another exposure of the Bug escarpment, **SU-2019** (Figs. 6B and 8), located to the north of the dry valley outlet, was measured in 2019. This section, starting from the water level, is composed of strongly compacted peats, 1.4 to 2 m thick, overlain by peaty silts (0.6 m), which accumulated in the Mazovian (Holsteinian) Interglacial and during the Early Liviecian (Fuhne) Glaciation (Żarski et al., 2023). Palaeobotanical analyses have not been carried out for this succession. Above the peaty silts occur fine niveofluvial sands, up to 0.5 m thick, correlated with the Odranian Glaciation. OSL absolute age determinations for these sands gave an age of 174 ±12 ka BP GdT I3811 (Żarski et al., 2023). The middle and upper part of the scarp is com-

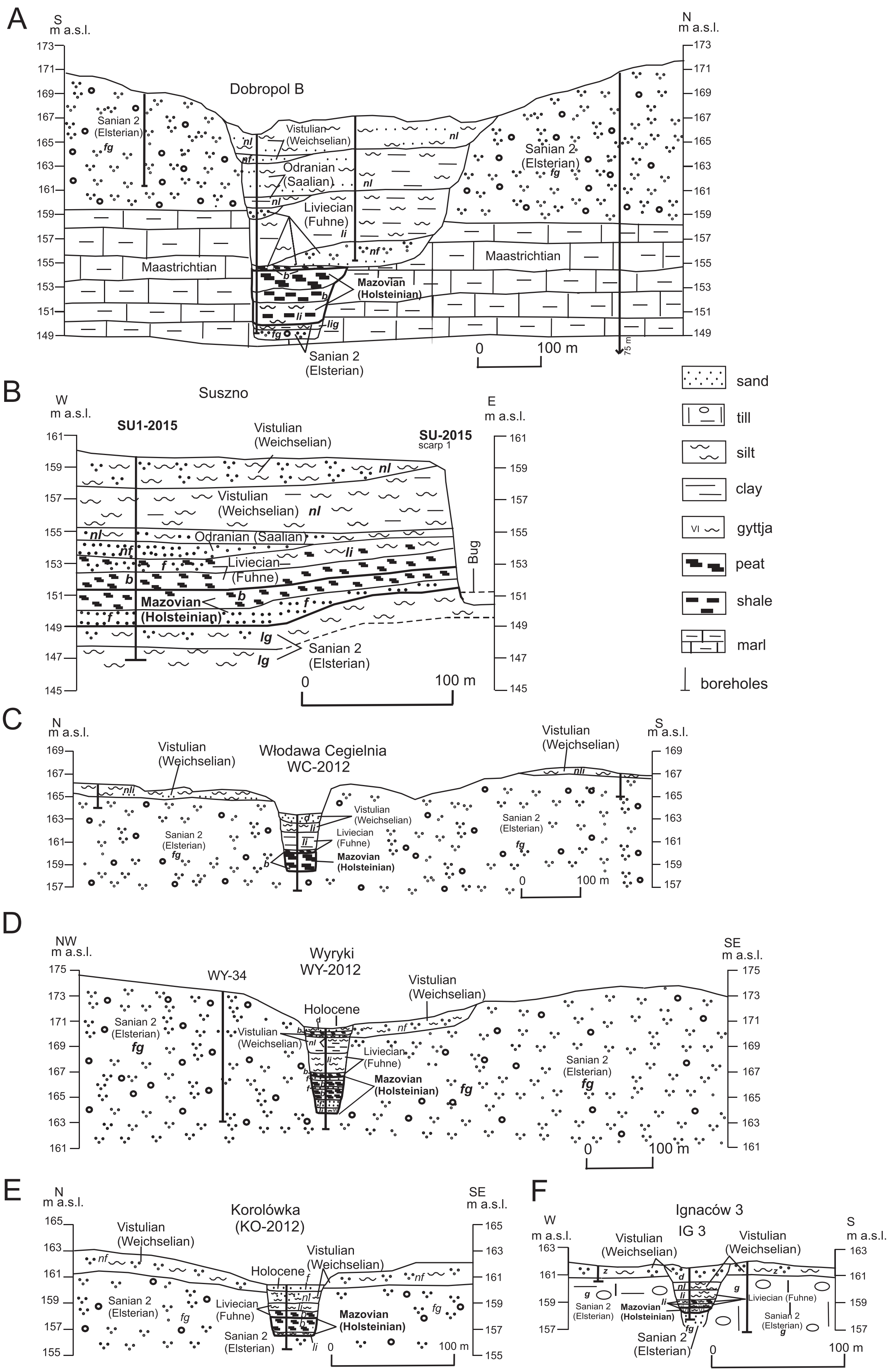

Fig. 7. Geological contexts of the sites analysed of the Mazovian (Holsteinian) Interglacial

g – glacial, fg – fluvioglacial, lg – limnoglacial, li – limnic, f – fluvial, nl – niveolimnic, nf – niveofluvial, d – deluvial, b – biogenic

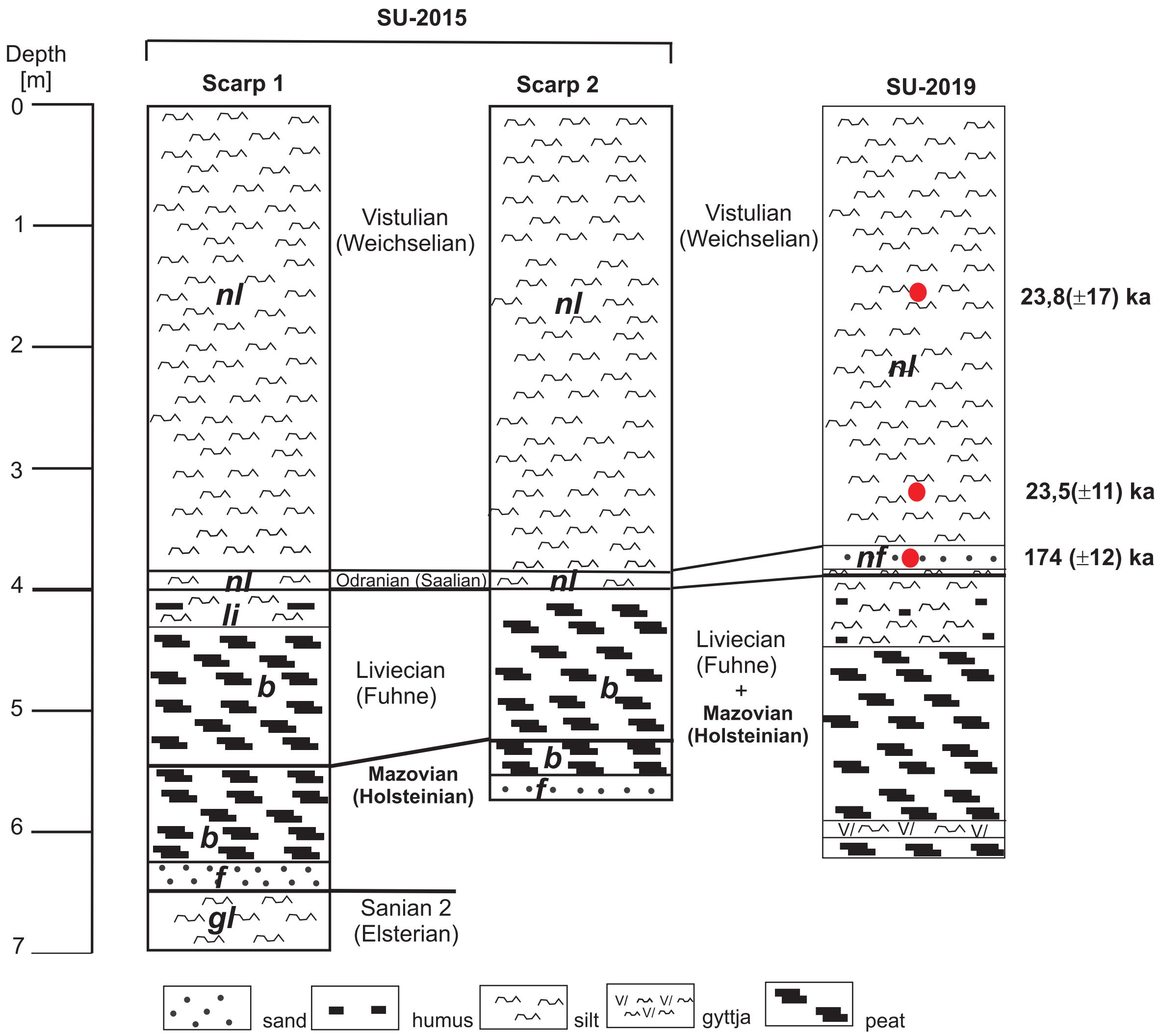

Fig. 8. Suszno on the Bug; lithological columns of the borehole SU-2015 (Scarp 1 and Scarp 2) and exposure SU-2019

gl – glaciolacustrine, li – limnic, f – fluvial, nf – niveofluvial, nl – niveolimnic, b – biogenic

posed of beige niveolimnic silts, ~4 m thick. OSL absolute age determinations were made on silt samples (SU-2019), resulting in ages of 23.8 and 23.5 ka PB, correlated with the upper Vistulian (Żarski et al., 2023; Marks et al., 2024).

Włodawa Cegielnia (WC-2012). This site with biogenic deposits is situated in an old brickyard, located to the south-east of Włodawa. The old pit lies in a wide depression, which is the beginning of a ~2 km long dry valley running to the Włodawka valley (Fig. 6C). The bottom of the pit is situated at an elevation of 163 m a.s.l., i.e. ~6–7 m below the surrounding terrain. Three cored boreholes, drilled in the pit in 1957, 1996 and 2012, documented peats of the Mazovian Interglacial (Stachurska, 1957; Obarska, 1996; Marszałek, 2000; Żarski et al., 2023).

In the **WC-2012** borehole (Fig. 7C), deposits of the Mazovian Interglacial are represented by 2.5 m of peat. Above, there is 0.35 m of peat from the Liviecian (Fuhne) Glaciation (Hrynowiecka in Żarski et al., 2023), overlain by Vistulian (Weichselian) niveolimnic clays and silts. Below the interglacial deposits occur fluvioglacial sands correlated with the Sanian 2 (Elsterian) Glaciation (Fig. 7C).

Wyryki (WY-2012). This site is located ~8 km to the south-west of Włodawa, in a place where two dry valleys meet; these later pass into a 4 km long, water-logged valley running into the Włodawka valley (Fig. 6D). The site lies at an elevation of 171 m a.s.l., i.e. several metres below the surrounding terrain built of fluvioglacial sands and gravels (Żarski and Morawski, 2019). A geoprobe WY-2012 borehole drilled in 2012 documented lacustrine and peat deposits. Palaeobotanical analyses indicated a vegetational succession typical of the Mazovian (Holsteinian) Interglacial (Żarski et al., 2023). The thickness of lacustrine, biogenic and fluvial deposits of the Mazovian Interglacial reaches ~2.4 m, the overlying peats of the Liviecian Glaciation are ~0.5 m thick and overlain by a silt layer (~2 m) of the same age (Fig. 7D). Above the Liviecian deposits occurs a 1.5 m thick succession of Vistulian niveolimnic silts and 0.5 m of Holocene peats. Below deposits of the Mazovian Interglacial there occur fluvioglacial sands and gravels representing the Sanian 2 Glaciation (Fig. 7D; Żarski and Morawski, 2019). The lacustrine deposits of the Mazovian Interglacial and the Liviecian Glaciation most probably infill a postglacial trough eroded into fluvioglacial deposits of the Sanian 2 Glaciation (Fig. 7D).

Korolówka (KO-2012). This site, with lacustrine and marsh deposits of the Mazovian Interglacial, is situated in a parallel-sided depression (Fig. 6E) incising the northeastern part of the Włodawa Heights, ~5 km to the north-west of Włodawa. The borehole KO-2012, drilled in 2012, was located above the Partyzantów Channel running to the Bug River (Żarski and Morawski, 2018, 2019). Palaeobotanical analyses of the lacustrine deposits have indicated a vegetational succession characteristic of the Mazovian Interglacial (Żarski et al., 2023). Beyond this depression, the terrain is composed of fluvioglacial sands and gravels, and rises to 161 m a.s.l. (Żarski and Morawski, 2019). Silts and peats of the Mazovian Interglacial documented in borehole KO-2012 (Fig. 7E) are 1.15 m thick. Above deposits of the Mazovian Interglacial occur peats of the Liviecian (Fuhne) Glaciation (0.45 m), followed by silts (0.5 m) of the same age (Żarski and Morawski, 2018, 2019; Żarski et al., 2023). These are overlain by Vistulian niveolimnic sandy silts (0.8 m) and Holocene fluvial sands (0.4 m). Lacustrine and biogenic deposits of the Mazovian Interglacial and Liviecian (Fuhne) Glaciation probably infill a shallow ancient post-glacial trough, eroded in fluvioglacial sands and gravels of the Sanian 2 (Elsterian) Glaciation (Fig. 7E) which lie at the base of the Mazovian (Holsteinian) Interglacial deposits (Żarski and Morawski, 2019).

Ignaców (IG 1). This site, with marsh and lacustrine deposits of the Mazovian Interglacial, is located on the northwestern, gently inclined slope of the Włodawa Heights, to the south of Zahajki (which is situated in the Sosnowica Depression; Fig. 6F). A borehole, Ignaców IG 1, hand-drilled in 2014 to the depth of 3.6 m documented the presence of lacustrine (silt) and marsh deposits (peats and peaty silts), whose age, based on palynological analyses, was attributed to the Mazovian (Holsteinian) Interglacial (Hrynowiecka et al., 2014). The interglacial deposits were encountered in the depth interval 1.9–3.5 m. Below the interglacial succession occur fluvioglacial sands representing the Sanian 2 (Elsterian) Glaciation (Żarski and Morawski, 2019). The interglacial deposits are overlain by Vistulian lacustrine and diluvial deposits. The interglacial succession described infills a melt-out depression after dead-ice, carved in glacial tills of the Sanian 2 (Elsterian) Glaciation, which build the surface of the post-glacial plateau.

A new borehole, Ignaców IG 3, was drilled in 2025 in the central part of the depression to obtain precise data for palaeobotanical studies (Fig. 6F). The cross-sections shown (Fig. 4C, D) include also sites sites at Kolonia Kaplonosy, PGR Korolówka and Kolonia Adampol with biogenic lacustrine deposits, whose age is at present correlated with the Mazovian (Holsteinian) Interglacial solely based on lithology and geological context.

MATERIAL AND METHODS

BOREHOLES

The borehole in Ignaców (Ignaców IG 3) was drilled using a hand probe (Eijkelkamp) to document the geological structure and collect samples for palaeobotanical analyses. The cross-sections, aimed at deciphering the geology of the study area, were based on lithological logs of boreholes available from the National Geological Archive and from unpublished data of the authors.

PALAEOBOTANICAL METHODOLOGY

Twenty 1 cm^3 samples (peats, gyttja) or 3 cm^3 (silts) were collected for palynological analysis from the core in Ignaców IG 3. Each sample was subject to the methodology described by Berglund and Ralska-Jasiewiczowa (1986) with acetolysis after Erdtman (1960). Pollen grains were identified under a light microscope at 400x magnification, using keys by Fægri and Iversen (1989), Moor et al. (1991), Reille (1992), and Beug (2004). In most cases, up to 500 pollen grains of arboreal (AP) and herbaceous (NAP) plants were counted, excluding aquatic and reedbed taxa. The diagrams were prepared with the application of *R Studio* software (Posit team, 2025) using the *riojaPlot* package (Juggins, 2022).

Plant macroremains were analysed in 21 samples (~40 cm^3 each) from the Ignaców IG 3 borehole core. They were collected with a resolution of 5 or 10 cm. After boiling with KOH to reduce the amount of sediment and remove humic matter, the samples were wet sieved on a ∅ = 0.18 mm mesh. The material obtained, including seeds, fruits and vegetative plant fragments, was analysed using a *Carl ZEISS Stemi 508* stereoscopic microscope. The macrofossils were identified on the basis of identification manuals and keys (e.g., Kats et al., 1965; Berggren, 1969; Cappers et al., 2006; Velichkevich and Zastawniak, 2006, 2008), and compared with a reference collection of modern diasporas, as well as specimens of fossil flora from the National Biodiversity Collection of Recent and Fossil Organisms stored at the W. Szafer Institute of Botany, Polish Academy of Sciences, in Kraków (herbarium KRAM). The results are shown in a macrofossil diagram created using *Polpal* software (Nalepka and Walanus, 2003).

RESULTS

New site of the Mazovian Interglacial: Ignaców IG 3. This new site with deposits of the Mazovian Interglacial, drilled in 2025, is located in the vicinity of borehole Ignaców IG 1 within the depression axis (Fig. 6F). The terrain surface is at an elevation of 161.5 m a.s.l., overlain by a thin weathering cover composed of sand and silts, and underlain by glacial tills of the Sanian 2 (Elsterian) Glaciation (Żarski and Morawski, 2019). Lake gyttja of the Mazovian Interglacial is only 0.33 m thick here and was drilled in the depth interval 1.98–1.65 m. Above, to the depth of 1 m occur peats and silts 0.65 m thick of the Early Liviecian Glaciation. Niveolimnic silts representing the Vistulian and diluvial sands overlie the Liviecian succession. Below occur fluvioglacial sands and gravels of the Sanian 2 Glaciation, which were not drilled through completely.

PALAEOBOTANIC ANALYSES

New data from the Ignaców IG 3 borehole. The pollen analysis of three samples from borehole Ignaców IG 1 revealed a pollen spectrum indicating the terminal part of the Mazovian Interglacial (*Carpinus–Abies* and *Pinus* phases), as well as the Early Liviecian Glaciation (Hrynowiecka et al., 2014; Żarski et al., 2023). It was anticipated that a more detailed analysis of newly obtained material from the Ignaców IG 3 borehole would enable a refined reconstruction of vegetational changes during

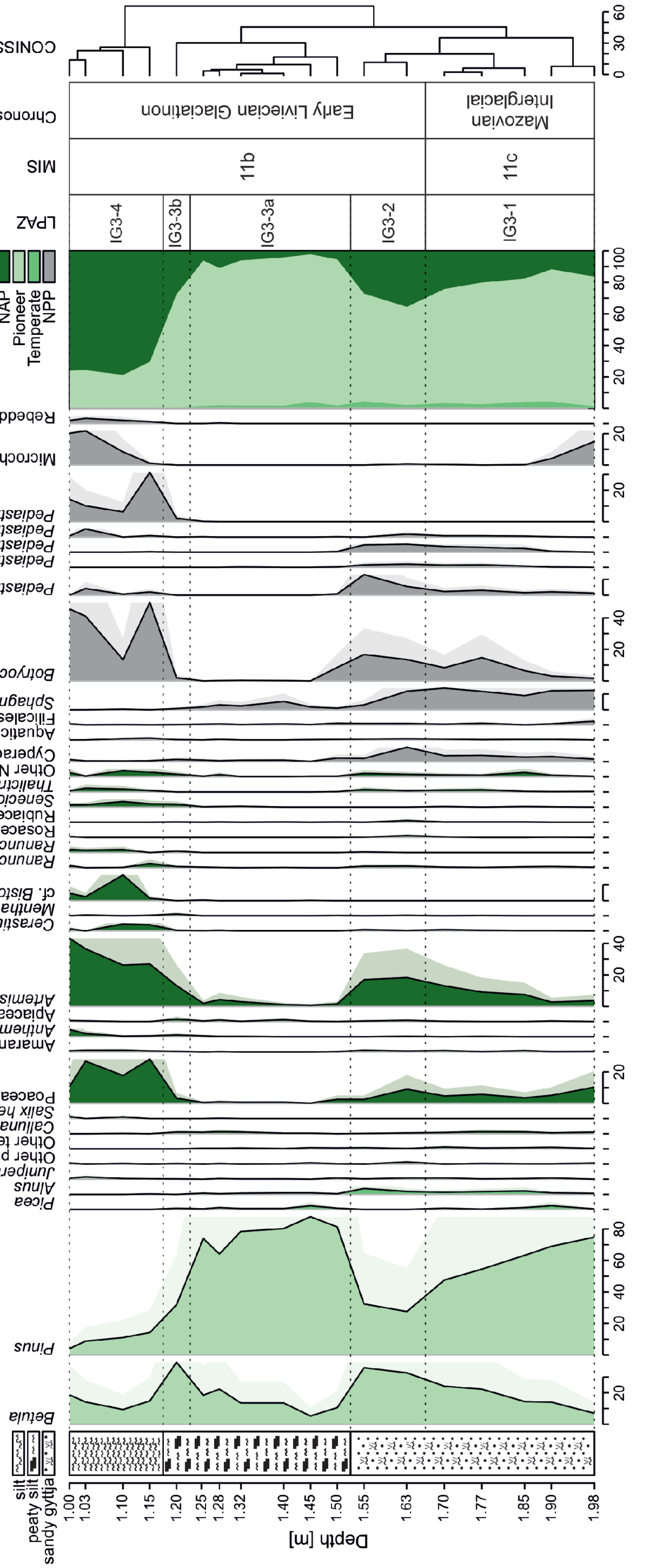

Fig. 9. Simplified pollen diagram for the Ignaców IG 3 borehole (analysis by A. Górecki)

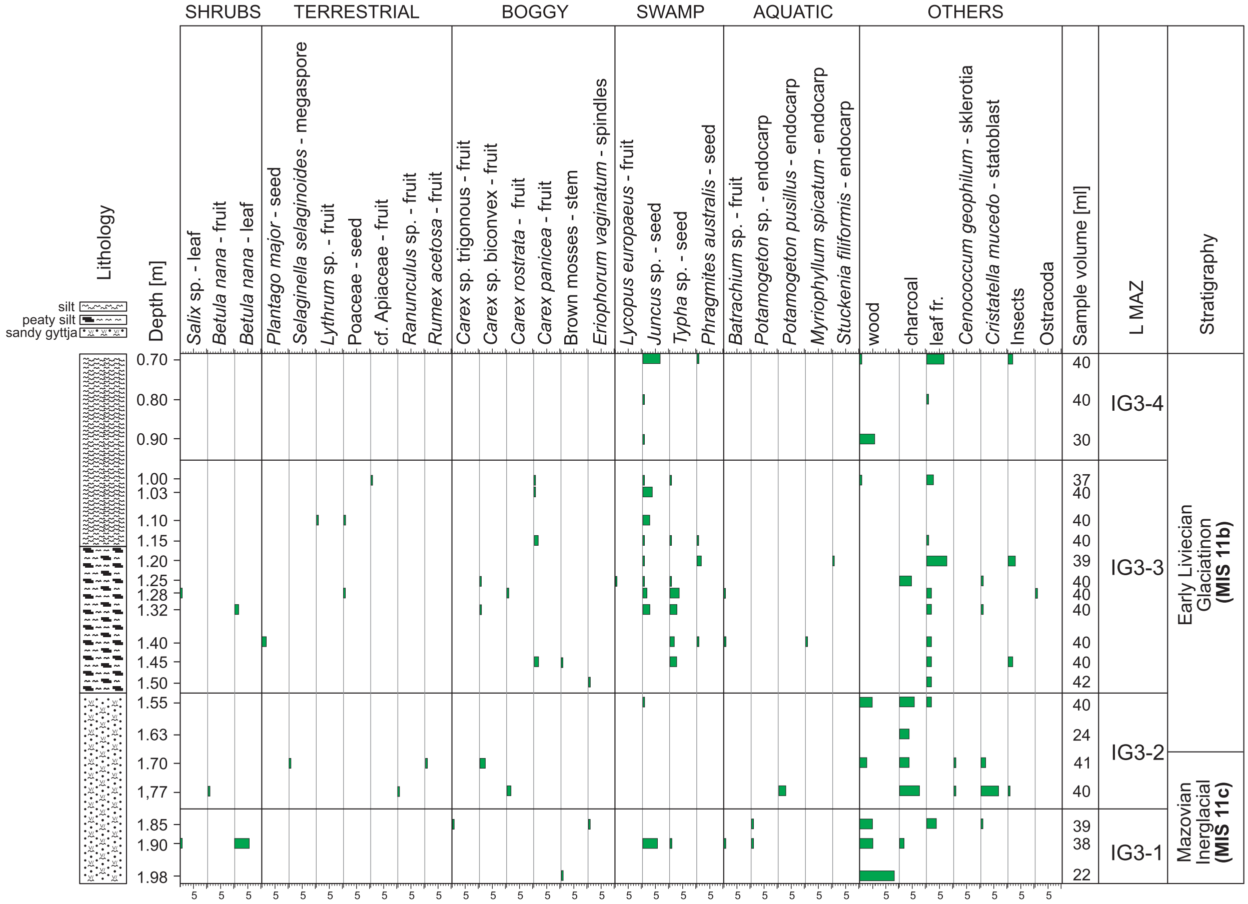

Fig. 10. Diagram of plant macroremains in the Ignaców IG 3 borehole (analysis by R. Stachowicz-Rybka and S. Skoczylas-Śniaz)

this interval. However, the newly obtained log revealed no evidence of the climatic optimum (Fig. 9). The Mazovian Interglacial is represented here only by the late *Pinus* phase (Fig. 9; LPAZ IG3-1), as suggested by the very limited presence of temperate taxa such as *Picea* and *Alnus*. The subsequent increase in NAP within LPAZ IG3-2 reflects glacial conditions of the first stadial of the Early Liviecian Glaciation (Fig. 9). The palynological spectrum of LPAZ IG3-3 is characteristic of the first interstadial of the Early Liviecian Glaciation, marked by a high proportion of *Pinus* and the occurrence of *Picea* pollen at the onset of *Subphase a*. *Subphase b* records climatic cooling with the development of a sparse *Pinus-Betula* woodland. In LPAZ IG3-4, the pollen assemblage is dominated by herbaceous taxa, indicating the expansion of open communities, most likely steppe, as indicated by the predominance of Poaceae and *Artemisia*. Noteworthy is the presence of pollen of *Bistorta vivipara*, a species with a relict distribution in contemporary Poland, restricted to the Carpathians (Zając and Zając, 2001). Phylogeographic studies, however, suggest that this taxon had a much wider distribution during glacial periods (Marr et al., 2013). Lake function is demonstrated by the presence of green alga fragments representing *Botryococcus* and *Pediastrum* among the palynological material. The high contribution of *Pediastrum kawraiskyi* suggests that the lake was oligotrophic and functioned in a cool climate (Jankovská and Komárek, 2000).

The Ignaców IG 3 borehole material was also subject to plant macrofossil analysis (Fig. 10). The samples contained a small amount of poorly preserved seeds and fruits. Twenty-seven taxa of various rank have been distinguished, and the presence of fragments of charcoal, wood, leaves, ostracod valves and insects was also determined. Four zones of plant macroremains were distinguished, corresponding to the terminal part of the Mazovian Interglacial (LMAZ IG3-1 and the basal part of LMAZ IG3-2) and the beginning of the Liviecian Glacial (top of LMAZ IG3-2, and LMAZ IG3-3 to IG3-4).

The presence of plant macroremains, such as leaves of *Betula nana* and most probably leaves with features similar to *Salix repens*, although this assignment is not certain and is retained at genus level (*Salix* sp.), was determined in LMAZ IG3-1 and IG3-2. This plant assemblage suggests that a cold climate prevailed at Ignaców at the end of the interglacial. Sparse pine-birch forests allowed the development of patches with light-sensitive vegetation, represented also by *Selaginella selaginoides*. Soil around the reservoir probably had a low trophic state as indicated by the presence of rusty peat moss and sclerenchymatous spindles of *Eriophorum vaginatum*.

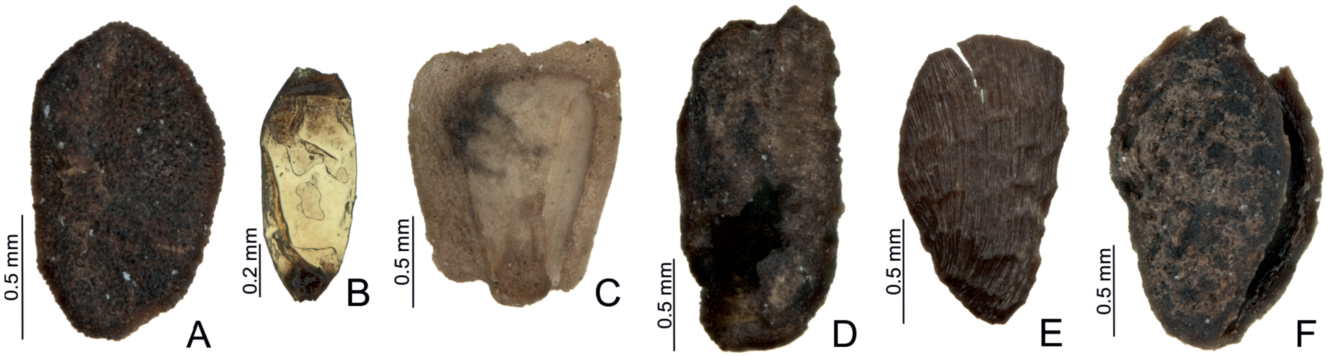

Fig. 11. Plant macroremains from the Ignaców IG 3 borehole (fot. K. Stachowicz)

A – *Plantago media*, **B** – *Typha* sp., **C** – *Lycopus europaeus*, **D** – *Myriophyllum spicatum*, **E** – *Batrachium* sp., **F** – *Potamogeton pusillus*

At that time *Batrachium* sp. (Fig. 11E) and *Potamogeton pusillus* (Fig. 11F) grew in the lake waters. The presence of *Batrachium* sp. was noted in the fourth, terminal phase of the Mazovian Interglacial at numerous sites, e.g. Podedwórze (Pochocka-Szwarc et al., 2024), and in the fourth phase of the Mazovian Interglacial and the early phase of the Liviecian Glacial at the following sites: Malice 3, Wielki Bór 1, Wielki Bór 2, Katowice 1 and Białe Ługi (Nita, 2009). Both *Batrachium* sp. and *Potamogeton pusillus* occurred also in the IVth terminal phase of the Mazovian Interglacial in Nowiny Żukowskie (Hrynowiecka and Szymczyk, 2011), which points to cold lake waters relatively poor in nutrients. Trophic decrease could result from climate cooling and the presence of pine in the close vicinity of the reservoir.

In the early part of the Liviecian (Fuhne) Glaciation, particularly in LMAZ IG3-3, the lake became shallower and vegetation similar to a great sedge swamp with *Lycopus europaeus* (Fig. 11C), *Carex rostrata*, *C. panicea*, *Typha* sp. (Fig. 11B), *Phragmites australis* and *Juncus* sp. encroaching on its surface. *Plantago media* (Fig. 11A) also grew at its margins. The water level in the lake could undergo periodical fluctuations. Periods of higher water levels are documented by the presence of *Batrachium* sp., *Myriophyllum spicatum* (Fig. 11D) and *Stuckenia filiformis*. In the last stage recorded in LMAZ IG3-4 only *Juncus* sp. seeds were found, which points to deposition in humid conditions.

SUMMARY OF PALYNOLOGICAL ANALYSES CONDUCTED SO FAR FROM THE WŁODAWA HEIGHTS

The preserved sporomorph assemblages are abundant and well-preserved, and across all profiles investigated the pollen succession follows the pattern characteristic of the Mazovian Interglacial. Each sequence displays the diagnostic features of MIS 11c vegetation development: an initial dominance of *Betula*, subsequently joined by *Pinus*; a mesocratic expansion of *Alnus* and *Picea* accompanied by the rise of *Taxus* (max. 10%); a prolonged climatic optimum marked by strong representation of *Carpinus* (max. 43%) and *Abies* (15%) together with other temperate forest taxa; and a late-interglacial phase characterized by renewed dominance of *Pinus* (Fig. 12). Numerous warm climate indices were determined, including *Pterocarya* and *Buxus* and other thermophylous taxa characteristic of the Mazovian Interglacial (Bińka et al., 2003; Winter, 2008; Table 2).

The presence of an intra-interglacial cooling, i.e. OHO (Older Holsteinian Oscillation; Koutsodendris et al., 2010) was also determined, with a significant share of *Pinus*, *Betula* and herbaceous plants (Fig. 12 and Table 2).

DISCUSSION AND FINAL REMARKS

The Włodawa Heights are an erosional outlier built of Pleistocene deposits, mainly representing the Sanian 1 and Sanian 2 glaciations. Their basement comprises Upper Cretaceous marine rocks (Fig. 3), and Pleistocene and Neogene deposits (Fig. 4A–C). The Włodawa Heights do not have any direct connection with the Variscan structural pattern, because during the Paleozoic the area was subject to subsidence. It is situated in the central part of a tectonic structure referred to as the Włodawa Depression (Żelichowski, 1984; Narkiewicz et al., 2007). Effects of disjunctive tectonics during the Alpine Orogeny are recorded as a network of a few minor faults with an orientation of NNE–SSW (Harasimiuk and Henkiel, 1984; Henkiel, 1984), NW–SE, and WNW–ESE (Herbich, 1980; Dobrowolski, 1995), developed in the Cretaceous basement. In the Włodawa Heights, as shown in the analysis of the cross-sections and a subcrop geological map, there occur NE–SW, NW–SE and N–S oriented faults.

Minor faults (Figs. 3 and 4A–E), registered in Maastrichtian rocks and related to the Alpine Orogeny, developed in the Late Cretaceous or Early Eocene (Laramide and Savian phases). This is indicated by minor tectonic grabens with an amplitude of 20–30 m, occurring in Maastrichtian marls and chalks and infilled with Middle and Upper Eocene and Lower Oligocene deposits (Figs. 3 and 4A–C). Most probably at that time older tectonic faults were reactivated, which could have led to the development of linear zones of weakened carbonate rocks, favouring the development of chemical denudation phenomena in the Early Paleocene (Harasimiuk, 1975; Henkiel, 1984; Maruszczak, 2001; Dobrowolski, 2006) or the development of sub-

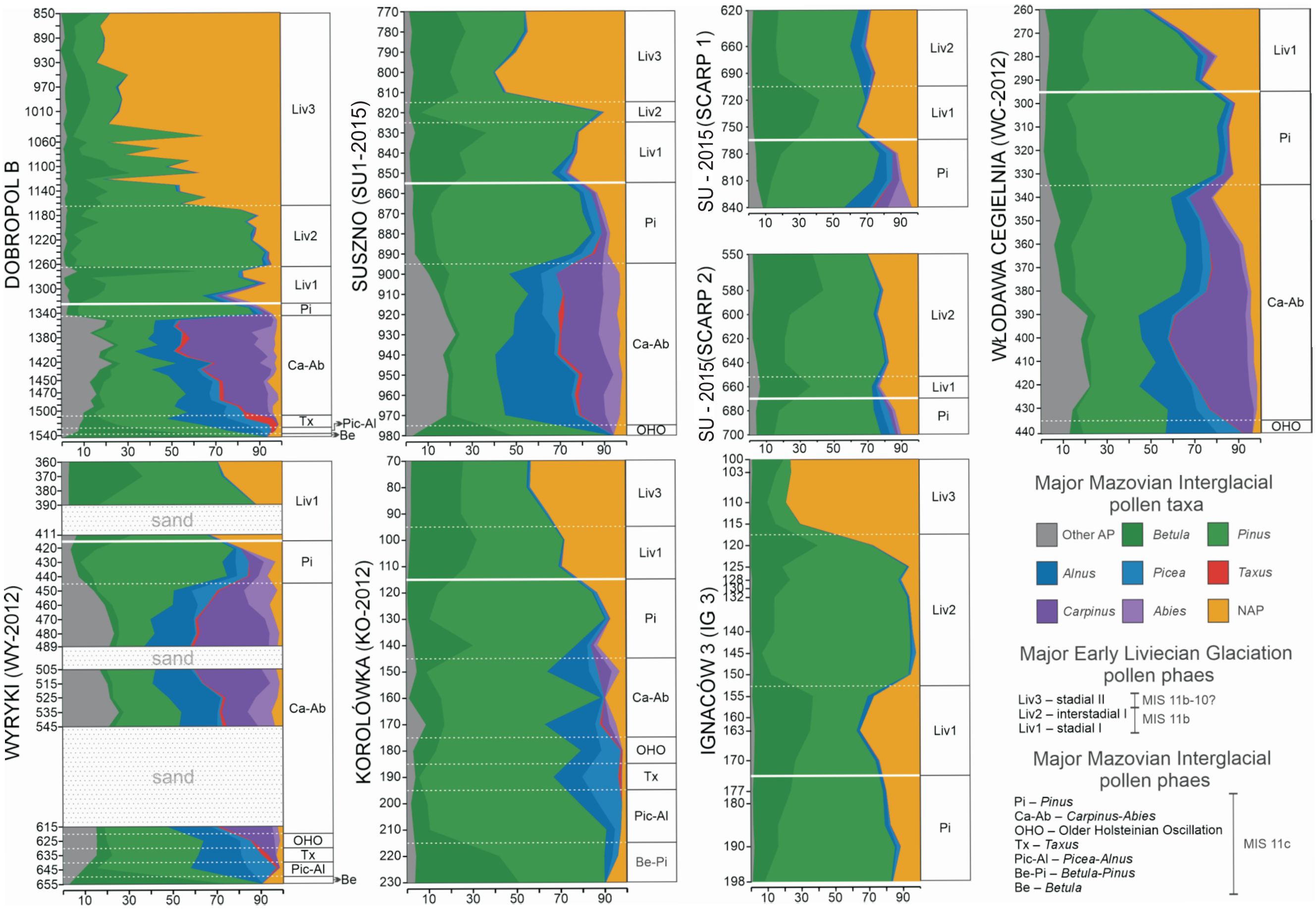

Fig. 12. Percentage content of taxa characteristic of the Mazovian Interglacial at particular sites (based on Hrynowiecka et al., 2014; Żarski et al., 2023)

Table 2

Percentage values of thermophilous species for particular sites (based on Hrynowiecka et al., 2014; Żarski et al., 2023)

Site	*Buxus*	*Carya*	*Celtis*	*Hedera helix*	*Juglans*	*Ligustrum*	*Parrotia*	*Pterocarya*	*Viscum*	*Vitis*
Dobropol B	1%	+	+	+	+	+	+	<4%	+	+
Suszno (SU1-2015)	+	–	–	+	–	–	+	+	+	+
Suszno (SU-2015) – Scarp 1	+	–	–	–	–	–	–	+	–	+
Suszno (SU-2015) – Scarp 2	+	–	–	–	–	–	–	–	–	+
Włodawa Cegielnia (WC-2012)	+	–	–	–	–	–	–	+	–	+
Wyryki (WY-2012)	+	–	–	–	–	–	+	+	–	–
Korolówka (KO-2012)	–	–	–	–	–	–	–	–	–	–
Ignaców 3 (IG 3)	–	–	–	–	–	–	–	–	–	–

glacial valleys or troughs in the Pleistocene. In the northern part of the Włodawa Heights, the Cretaceous basement includes faults with throws of 20–30 m (Figs. 3 and 4A, B), which could have been a potential obstacle for the advancing ice-sheets during the Pleistocene, and favouring glaciotectonic deformation. In the northern part of the Włodawa Heights, Cretaceous rocks are tectonically elevated with respect to the Sosnowica Depression by 20–30 m (Fig. 4A), in some cases exceeding these values. Near Kol. Kaplonosy–Kol. Połód, this difference is 60 m (Fig. 4D), and the top surface of the Cretaceous rises from 100 to 160 m a.s.l. It seems that such a low position of the top of the Maastrichtian was caused by fluvioglacial erosion from the melting Sanian 1 and Sanian 2 (Elsterian) ice-sheet. Summing up, there is no unequivocal evidence for the reactivation of older faults (initiated during the Variscan deformation) during Alpine tectonism. At the same time, Upper Maastrichtian rocks occurring below the Włodawa Heights do not represent an elevation developed during Alpine tectonism, with the exception of its northern margin.

PALAEOGEOGRAPHIC DEVELOPMENT

The ice-sheet of the Sanian 1 (Glacial B) Glaciation encroached on the variable morphology of the Cretaceous-Paleogene terrain, accumulating at first glacial tills, and then ice-dammed silts and clays, as well as fluvioglacial sands and gravels. Within the Włodawa Heights only two horizons of glacial till occur, correlated with the Sanian 1 and Sanian 2 glaciations. The hypothesis of a twofold coverage of Włodawa Heights by the ice-sheet was corroborated by the analysis of the geological setting of sites with Mazovian Interglacial deposits, e.g. in Brus (Pidek, 2003; Hrynowiecka and Pidek, 2017). In that succession two levels of glacial till corresponding to the Sanian 1 and Sanian 2 (Glacial B and Elsterian) glaciations separated by fluvioglacial deposits occur below the Mazovian Interglacial deposits (Fig. 4A).

Most probably, during the retreat of the Sanian 1 Glaciation, systems of glacial water runoff existed in the eastern part of the heights. Water flowing under intense and variable pressure eroded the basement, creating post-glacial troughs (Kirkham et al., 2024). During the Ferdynandovian Interglacial (Cromerian III), the post-glacial trough eroded in glacial tills of the Sanian 1 (Glacial B) Glaciation (in Sosnowica; Fig. 4E) was infilled by lacustrine sediments and peats (Janczyk-Kopikowa, 1987, 1991; Stachowicz-Rybka et al., 2017). Most probably, intense erosion by waters from the melting ice-sheet took place during the retreat of the Sanian 1 ice-sheet; these caused erosion of older Pleistocene deposits in the eastern part of the Włodawa Heights and shaped the outline of the Sosnowica Depression (Fig. 4A–E; Pochocka-Szwarc et al., 2024). However, this is problematic and it is quite possible that the entire fluvioglacial succession may be of a similar age and represent the Sanian 2 Glaciation. Subsequent advance of the Sanian 2 (Elsterian) ice-sheet caused the accumulation of glacial, fluvioglacial and ice-dammed sediments. Glacial tills of this glaciation covered the lacustrine deposits of the Ferdynandovian (Cromerian IV) Interglacial in Sosnowica. The ice-sheet of the Sanian 2 (Elsterian) Glaciation reached farther to the south, beyond the study area (to the SE of Przemyśl; Łanczont et al., 2019), or to the catchment of San and Wisłok (Lindner and Marks, 2015).

Traces related to the recessional phases of this ice-sheet are recorded in Western Polesie. An ice-sheet stopover in the form of hills of frontal moraines preserved in the terrain morphology is recorded in the topmost part of the Włodawa Heights (vicinity of Marianka), as well as near Różanka and Kolonia Stawki (Pochocka-Szwarc and Żarski 2023; Żarski and Pochocka-Szwarc, 2025; Orłowska et al., 2025). During the Sanian 2 (Elsterian) ice-sheet recession, in the eastern parts of the heights [as during the Sanian 1 (Glacial B) Glaciation] a zone of water runoff from the melting ice-sheet formed. The effect of these processes are covers of fluvioglacial sands and gravels, over 10 m thick, building the terrain surface. Several N–S oriented post-glacial troughs, whose outline is still distinct in the morphology, are preserved within the Włodawa Heights (Żarski and Morawski, 2018, 2019). These troughs are usually filled with fluvioglacial deposits. Erosion of water from the melting Sanian 2 ice-sheet caused the destruction of glacial deposits in the Sosnowica Depression and the Łęczna-Włodawa Lakeland, resulting in the development of an erosional outlier, i.e. the Włodawa Heights. Fluvioglacial sands and gravels from the Sanian 2 Glaciation build part of the Sosnowica Depression area except for its surface (Pochocka-Szwarc et al., 2024). Most probably the runoff of fluvioglacial waters during the ice-sheet retreat took place at least in two directions: N–S in the eastern part of the Włodawa Heights, i.e. parallel to the present-day Bug valley, and E–W along the Sosnowica Depression axis and in the Łęczna-Włodawa Lakeland. The question of water runoff after the recession of the Sanian 1 and Sanian 2 ice-sheets requires further study. After the retreat of the Sanian 2 ice-sheet, the present day Bug River valley began to be shaped.

PALAEOBOTANICAL EVIDENCE

All sites described in this article, Dobropol, Suszno (boreholes and scarp exposures), Włodawa Cegielnia, Wyryki, Korolówka and Ignaców (Fig. 13), show features characteristic of the Mazovian succession. The oldest (birch) phase was observed in Dobropol and Wyryki (Fig. 12). The birch-pine phase is recorded only in Korolówka. The mesocratic alder-spruce phase and the characteristic phase with abundant yew are observed in Dobropol, Wyryki and Korolówka. The OHO is recorded in Suszno, Włodawa Cegielnia, Wyryki and Korolówka (Fig. 12). The climatic optimum of the Mazovian Interglacial with the domination of fir, hornbeam, and numerous warm climate indices is recorded in Dobropol, Suszno, Włodawa Cegielnia, Wyryki, and Korolówka. In turn, the second main oscillation of the Mazovian Interglacial, the YHO (Younger Holsteinian Oscillation; Koutsodendris et al., 2010), is not recorded in sections from the Włodawa Heights. Its lack is surprising, owing to the large thickness of the *Carpinus-Abies* phase and high-resolution sampling. The telocratic pine phase, followed by the Liviecian cooling, are recorded in the deposits of all sites analysed.

Crucially, in all 6 sites described, glacial deposits do not occur above the lacustrine and peat deposits of the Mazovian Interglacial (Hrynowiecka et al., 2014; Żarski et al., 2023). Thus, the Włodawa Heights were not covered by the ice-sheet of the Odranian (Saalian) Glaciation, as previously thought (Buraczyński and Wojtanowicz, 1983; Buraczyński et al., 1984; Buraczyński, 1986; Dolecki et al., 1991, 1994; Dolecki and Wojtanowicz, 1992; Lindner, 1996).

ORIGIN AND AGE OF THE BUG VALLEY IN RELATION TO THE SITES WITH MAZOVIAN INTERGLACIAL DEPOSITS

In the Bug valley scarp in Suszno, fluvial sands and gravels of the Mazovian Interglacial occur within lacustrine deposits (Trembaczowski, 1957; Stachurska, 1960, 1961; Mojski and Trembaczowski, 1961; Marszalek, 2000; Żarski et al., 2023). And, the data of Lilpop (1925a, b) on the occurrence of peats in the Bug River scarp in Włodawa and nearby Koszary in Ukraine may suggest that the lateral range of interglacial lacustrine and marshy sediments was originally much wider, probably as infills of palaeochannels overgrown during a certain stage of the palaeoriver activity. A similar situation was recognized in boreholes in Syrniki (Wieprz valley) to the south of Lubartów (Mojski, 1964; Łozińska-Stępień et al., 1985; Kucharska et al., 2024), where lacustrine and fluvial deposits of the Mazovian Interglacial presently exposed in the river channel occur below Holocene and Vistulian Glaciation deposits.

Most probably, during the Mazovian Interglacial, the contemporary pre-Bug utilised a post-glacial trough, formed during the recession of the Sanian 2 Glaciation, which incised the Qua-

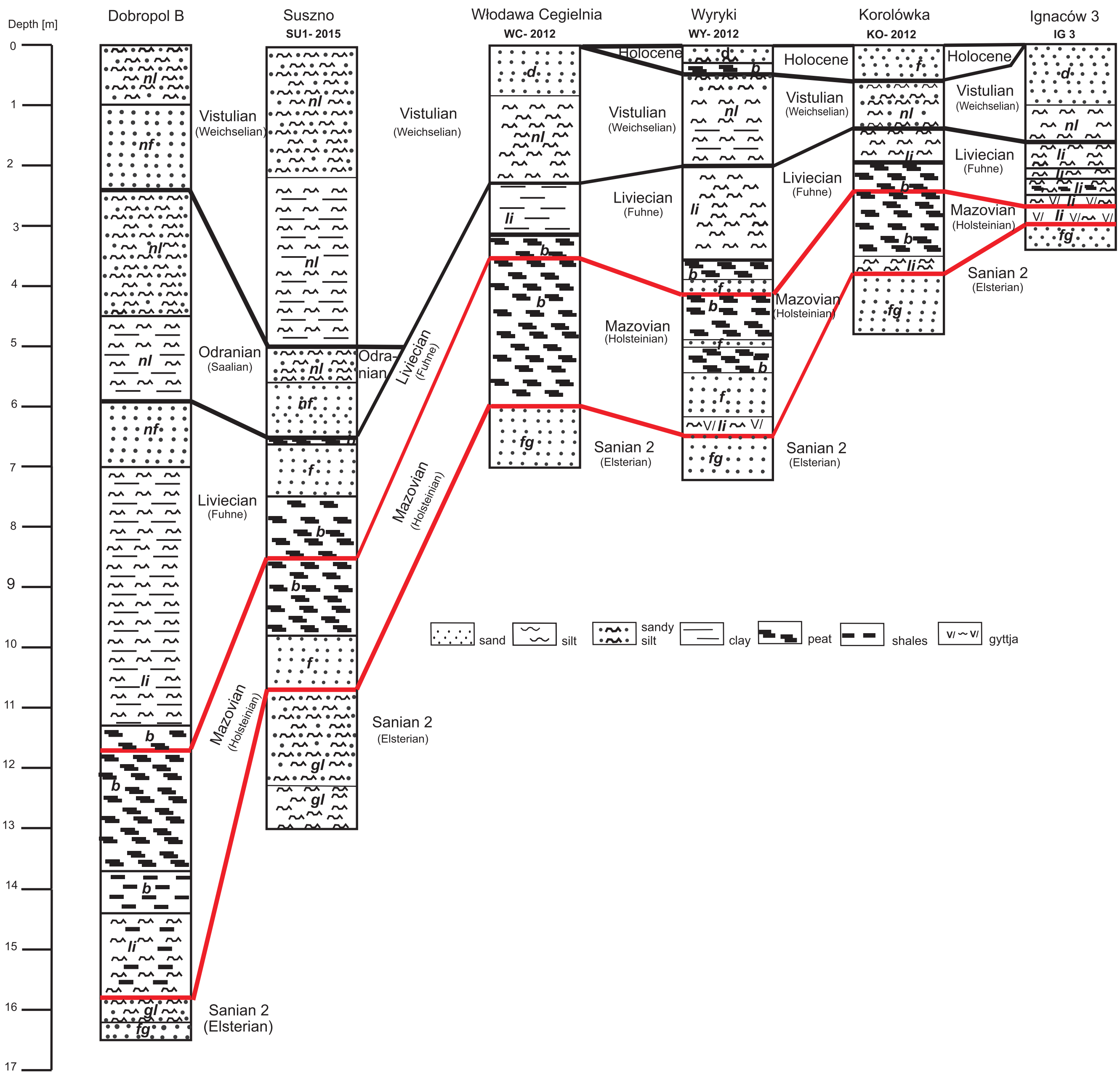

Fig. 13. Comparison and correlation of the lithological columns of the sites analysed

fg – glaciofluvial, gl – glaciolacustrine, f – fluvial, li – limnic, nl – niveolimnic, nf – niveofluvial, d – deluvial, b – biogenic

ternary deposits building the present-day Włodawa Heights. After the Mazovian Interglacial, fluvial runoff ceased until the Late Pleistocene (Vistulian), when the present-day Bug valley was shaped. This is indicated by fluvial deposits building the alluvial terraces of the Bug located to the north and south of the Włodawa Heights (Pochocka-Szwarc and Żarski, 2023).

Reconstruction of the geological context of the Mazovian (Holsteinian) Interglacial is of crucial importance for the interpretation of the Włodawa Heights geology. A characteristic feature of most sites with deposits of the Mazovian Interglacial (with the exception of Ignaców) is the fact that lacustrine and marshy sediments infilled post-glacial troughs from the Sanian 2 Glaciation. Most probably, during the ice-sheet retreat these were filled with dead ice, after the melting of which depressions were created; they were filled with lake waters and later also became peatlands (Błaszkiewicz, 2008). It cannot be excluded that brief fluvial runoff could have existed in some of them, as in the case of the pre-Bug River. This is demonstrated by sand interbeds observed in Wyryki (Fig. 12), deposited during the Mazovian Interglacial climate optimum (*Carpinus-Abies* phase). Interestingly, most ancient post-glacial troughs are clearly visible in the terrain as valleys that run into the Włodawka valley (Dobropol, Włodawa Cegielnia, Wyryki) or directly into the Bug (Korolówka, Suszno – SU-2015). This is linked with the next issue: the presence of fine-grained deposits, i.e. silts, silty sands and clays correlated with the Odranian (Saalian) or Vistulian

(Weichselian) glaciations (Marks et al., 2024) above deposits of the Mazovian Interglacial or the Early Liviecian (Fuhne). These fine-grained deposits do not occur beyond the present-day valley depressions.

Most probably, during the Odranian (Saalian MIS 6) and Vistulian (Weichselian MIS 2-5d) glaciations, lakes were present in the palaeotrough depressions; these were infilled with silty-clay sediments overlying deposits of the Mazovian Interglacial and Liviecian Glaciation. This was probably caused by a rise of the erosional base level in the ice-sheet hinterland (Marks et al., 2024).

The greatest thickness of the fine-grained reservoir deposits, reaching over 11 m (Fig. 13), was noted in Dobropol B. In Suszno, in borehole SU-2015, the thickness of the deposits above the peats of the Mazovian Interglacial exceeds 6 m. In Włodawa Cegielnia there are ~3 m of Vistulian silts, clays and sands and in Wyryki there are ~1.5 m of Vistulian clayey silts above Liviecian peats (Fig. 13). The Ignaców site is located in a palaeolake carved into glacial tills. Here, the thickness of Vistulian diluvial deposits overlying those of the Mazovian Interglacial is a little over 1 m.

CONCLUSIONS

1. The Włodawa Heights are located within a Paleozoic structural unit known as the Włodawa Depression, originally shaped in the Carboniferous, overlain by a unfaulted succession of Jurassic and Cretaceous rocks. The present-day morphology of the Włodawa Heights does not correspond to the Variscan structural plan.

2. The Włodawa Heights represent a sub-parallel-sided morphological form composed of Pleistocene deposits, resting on a basement comprising Upper Maastrichtian, Middle and Upper Eocene, Lower Oligocene and Middle Miocene rocks.

3. The Włodawa Heights do not represent an elevation of Cretaceous rocks. Only their northern margin has a tectonic foundation, with faults with displacements of 20–30 m within Maastrichtian rocks. These faults formed a small ridge for the advancing ice-sheets of the South Polish Glaciations and predisposed the development of glaciotectonic deformation of Quaternary, as well as Paleogene-Neogene strata. The top of the Maastrichtian rises towards the south-east: in the Włodawa Heights it rises to 130–160 m a.s.l., and farther to the south in the Łęczna-Włodawa Lakeland it occurs at elevations of 160–190 m a.s.l. and forms exposures.

4. The top of Upper Maastrichtian rocks is undulose, which is probably the result of tectonic deformation (faulting) during the Alpine Orogeny, as well as erosional activity and chemical denudation of carbonate rocks (karst in the Paleogene).

5. The Włodawa Heights were covered twice by the ice-sheets of the Sanian 1 (Glacial B, MIS 16) and Sanian 2 (Elsterian, MIS 12) glaciations, as indicated by two horizons of glacial till separated by deposits of the Ferdynandovian Interglacial (Cromerian Complex, MIS 15-13) in Sosnowica.

6. Evidence for the ice-sheet standstill of the Sanian 2 (Elsterian, MIS 12) Glaciation in the recessive phase are hills of frontal moraines (e.g., in the vicinity of Marianka) located on the highest parts of the heights and oriented along their morphological axis.

7. The Włodawa Heights represent an erosional outlier formed due to erosion by fluvioglacial waters during the recession of the Sanian 2 (Elsterian, MIS 12) Glaciation.

8. Sites with lacustrine and biogenic deposits from the Mazovian (Holsteinian) Interglacial which are not overlain by glacial deposits occur at the surface of the Włodawa Heights. These deposits infill post-glacial palaeotroughs and melt-out depressions formed after melting of the ice-sheet of the Sanian 1 and Sanian 2 glaciations.

9. The Mazovian Interglacial, followed by the Liviecian (Fuhne, MIS 10) Glaciation, is recorded in the deposits of the sites analysed. The characteristic succession shows a typical arrangement of woody vegetation phases. These include (from the oldest): birch phase, pine-birch-pine phase, alder-spruce phase, yew phase, OHO cooling, fir-hornbeam phase, pine phase, and the development of vegetation typical for the climate of the Early Liviecian Glaciation. Climate changes are recorded in lacustrine and marsh facies.

10. Initially, the Bug River valley incising the Włodawa Heights was probably a sub-glacial trough of the Sanian 2 (Elsterian, MIS 12) Glaciation ice-sheet. In the Mazovian Interglacial a progressively overgrown lake probably existed along the Suszno–Włodawa–Koszary line, in which mainly peats accumulated. After the Mazovian Interglacial there was no fluvial runoff in the Bug valley. This reappeared in the Vistulian, shaping the present-day Bug valley (in the stretch analysed).

11. At the sites analysed, above deposits of the Mazovian (Holsteinian, MIS 11c) Interglacial and Liviecian (Fuhne) Glaciation occur a thick succession of lake deposits from the Odranian Glaciation (Saalian, MIS 6), and fine niveofluvial and niveolimnic deposits from the Vistulian.

Author contribution. M. Żarski and K. Pochocka-Szwarc studied the geology of Włodawa Heights based on five charts of the Detailed Geological Map of Poland at 1:50,000 scale, the 1:250,000 scale map, the Włodawa chart of the map at the 1:200,000 scale, and results of research projects. A. Hrynowiecka was responsible for the palaeobotanical analysis of most sites with deposits representing the Mazovian Interglacial. A. Górecki made the palaeobotanical analysis of site Ignaców 3, whereas the macro remains from the same site were analysed by R. Stachowicz-Rybka, S. Skoczylas-Śniaz and K. Stachowicz. A synthetic compilation of plant species characteristic of the Mazovian Interglacial in selected sites was made by A. Hrynowiecka and A. Górecki. M. Pielach was responsible for models of the terrain morphology and of the top of the Maastrichtian rocks.

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REFERENCES

Albrycht, A., 2004. Objaśnienia do Szczegółowej Mapy Geologicznej Polski 1:50 000, arkusz Sarnaki (531) (in Polish). CAG PIG, Warszawa, nr 2471/99.

Albrycht, A., 2005. Szczegółowa Mapa Geologiczna Polski 1:50 000, arkusz Sarnaki (531) (in Polish). CAG PIG, Warszawa, nr 2471/99.

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

Areń, B., 1974. Budowa geologiczna pokrywy osadowej na podstawie głębokich otworów wiertniczych i badań sejsmicznych (in Polish). Prace Instytutu Geologicznego, **74**: 7–19.

Berggren, G., 1969. Atlas of seeds and small fruits of northwest-European plant species with morphological descriptions. Part 2. Cyperaceae. Stockholm, Swedish Natural Science Research Council.

Berglund, B.E., Ralska-Jasiewiczowa, M., 1986. *Pollen analysis* and pollen diagrams. In: Handbook of Holocene Palaeoecology and Palaeohydrology (ed. B.E. Berglund): 455–484. John Wiley and Sons Press, Chichester.

Beug, H.J., 2004. Leitfaden der Pollenbestimmung für Mitteleuropa und angrenzende Gebiete (Guide to the Pollen Analysis for Central Europe and the Adjacent Areas). Pfeil, München.

Bińka, K., Nitychoruk, J., Dzierżek, J., 2003. Parrotia persica C.A.M. (Persian witch hazel, Persian ironwood) in the Mazovian (Holsteinian) Interglacial of Poland. Grana, **42**: 227–233.

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

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

Buraczyński, J., 2013. Rozwój rzeźby Roztocza (in Polish). Wydaw. Wyższej Szkoły Społeczno-Przyrodniczej im. Wincentego Pola, Lublin.

Buraczyński, J., Wojtanowicz, J., 1980. Zaburzenia glacitektoniczne osadów zlodowacenia środkowopolskiego w zachodniej części Garbu Włodawskiego (in Polish). In: Przewodnik Seminarium: Stratygrafia i chronologia lessów oraz utworów glacjalnych dolnego i środkowego plejstocenu w Polsce SE: 89. Lublin.

Buraczyński, J., Wojtanowicz, J., 1980/81. The effect of the Middle-Polish Glaciation on the relief of southern part of Polesie Lubelskie (in Polish with English summary). Annales Universitatis Mariae Curie-Skłodowska, Sect. B, **35/36:** 63–79.

Buraczyński, J., Wojtanowicz, J., 1981. Szczegółowa Mapa Geologiczna Polski w skali 1:50 000, arkusz Kołacze (716) (in Polish). CAG PIG, Warszawa, nr 4337/99.

Buraczyński, J., Wojtanowicz, J., 1982. Objaśnienia do Szczegółowej Mapy Geologicznej Polski w skali 1:50 000, arkusz Kołacze (716) (in Polish). CAG PIG, Warszawa, nr 4337/99.

Buraczyński, J., Wojtanowicz, J., 1983. The effect of the Middle Polish Glaciation on the relief of southern part of Polesie Lubelskie (in Polish with English summary). Annales Universitatis Mariae Curie-Skłodowska Sec. B, **35/36**: 63–79.

Buraczyński, J., Butrym, J., Wojtanowicz, J., 1984. Dating of the fossil glacial lake in Marianka on the Włodawa range (in Polish with English summary). Annales Universitatis Mariae Curie-Skłodowska Sec. B, **39**: 91–104.

Cappers, R.T.J., Bekker, R.M., Jans, J.E.A., 2006. Digital seed atlas of the Netherlands. Groningen, Barkhuis/Groningen University Library.

Dobrowolski, R., 1995. Mesoscopic tectonic structures in the Upper Cretaceous rocks in the eastern part of the Lublin Upland versus faulting of the East-European Platform basement during the Cainozoic (in Polish with English summary). Annales Societatis Geologorum Poloniae, **65**: 79–91.

Dobrowolski, R., 2006. Glacial and periglacial transformation of karst relief in the northern foreland of the Lublin-Volhynia uplands (SE Poland, NW Ukraine) (in Polish with English summary). Wydaw. Universitatis Mariae Curie-Skłodowska, Lublin.

Dobrowolski, R., Chabudziński, Ł., 2021. Garb Włodawski (in Polish). In: Regionalna geografia fizyczna Polski (eds. A. Richling, J. Solon, A. Macias, J. Balon, J. Borzyszkowski and M. Kistowski): 581–582. Wydaw. Bogucki, Poznań.

Dobrowolski, R., Harasimiuk, M., 2002. Geological conditions of relief development in the Polesie. Acta Agrophysica, **66**: 7–19.

Dolecki, L., Wojtanowicz, J., 1992. Lithology and stratigraphy of Pleistocene sediments in the southwestern Włodawa Elevation (Lublin Polesie) (in Polish with English summary). Annales Universitatis Mariae Curie-Skłodowska Sec. B, **47**: 25–65.

Dolecki, L., Gardziel, Z., Nowak, J., 1987. Szczegółowa Mapa Geologiczna Polski w skali 1:50 000, arkusz Sosnowica (679) (in Polish). CAG PIG, Warszawa, nr 10480/2025.

Dolecki, L., Gardziel, Z., Nowak, J., 1990. Objaśnienia do Szczegółowej Mapy Geologicznej Polski w skali 1:50 000, arkusz Sosnowica (679) (in Polish). CAG PIG, Warszawa, nr 10480/2025.

Dolecki, L., Gardziel, Z., Nowak, M., 1991. Nowe stanowisko interglacjału ferdynandowskiego w Sosnowicy (Polesie Lubelskie) (in Polish). Geografia, **50**: 409–417.

Dolecki, L., Harasimiuk, M., Wojtanowicz, J., 1994. Stratigraphy of glacial formation of the Middle and Upper Pleistocene in South-East Poland (in Polish with English summary). Annales Universitatis Mariae Curie-Skłodowska Sec. B, **49**: 19–31.

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

Fægri, K., Iversen, J., 1989. Textbook of Pollen Analysis (eds. K. Fægri, P.E. Kaland and K. Krzywinski). John Wiley and Sons, Chichester.

Gagel, K., 1922. Geologiche Beobachtungen aus Wolhynien. Vergleichende Studien über wolhynischen und deutschen Löss. Jahrbuch der Königlich Preussischen Geologischen Landesanstalt und Bergakademie, **43**: 273–322.

Gagel, K., Korn, K., 1908. Geschiebeinhalt des volhynischen Diluvium. Zeitschrift der Deutschen Geologischen Gesellschaft, **70**: 5–7.

Gawor-Biedowa, E., 1992. Campanian and Mastrichtian Foraminifera from the Lublin Upland, Eastern Poland. Palaeontologia Polonica, **52**:11–187.

Górecki, A., Żarski, M., Drzewicki, W., Pleśniak, Ł., Zalewska-Gałosz, J., 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; https://doi.org/10.1016/j.quaint.2021.09.017

Harasimiuk, M., 1975. Relief evolution of the Chełm Hills in the Tertiary and Quaternary (in Polish with English summary). Prace Geograficzne, **115**.

Harasimiuk, M., Henkiel, A., 1984. Kenozoik Lubelskiego Zagłębia Węglowego (in Polish). In: Przewodnik. 56. Zjazdu Polskiego Towarzystwa Geologicznego: 56–69. Wydaw. Geol., Warszawa.

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

Henkiel, A., 1984. Tectonics of Meso-Cainozoic Cover of the Northern Slope of the Metacarpathian Swell (in Polish with English summary). Annales Universitatis Mariae Curie-Skłodowska Sec. B, **39**: 13–38.

Herbich, P., 1980. Tektoniczne uwarunkowania horyzontalnej anizotropii warunków wodoprzepuszczalności utworów kredy górnej okolic Chełma (in Polish). Technika Poszukiwań Geologicznych, **19** (3): 27–32.

Hrynowiecka, A., Pidek, A., 2017. Older and Younger Holsteinian climate oscillations in the palaeobotanical record of the Brus profile (SE Poland). Geological Quarterly, **61**: 723–737; https://doi.org/10.7306/gq.1358

Hrynowiecka, A., Szymczyk, A., 2011. Comprehensive palaeobotanical studies of lacustrine-peat bog sediments from the Mazovian/Holsteinian interglacial at the site of Nowiny Żukowskie (SE Poland) – preliminary study. Bulletin of Geography – Physical Geography Series, **4**: 21–46.

Hrynowiecka, A., Żarski, M., Winter, H., 2014. Vegetation and stratigraphy of the Mazovian (Holsteinian) interglacial sections from Dobropol and other new sites in Western Polesie region (south-eastern Poland). Studia Quaternaria, **31**: 17–30; https://doi.org/10.2478/squa-2014-0002

Hrynowiecka, A., Żarski, M., 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 Quaterly, **63**: 375–394; https://doi.org/10.7306/gq.1470

Janczyk-Kopikowa, Z., 1981. Orzeczenie dotyczące próbek z miejscowości Brus 1, Wólka Petryłowska 18 (in Polish). Opracowanie specjalne dla arkusza Kołacze. CAG PIG, Warszawa,. nr 10407/2025.

Janczyk-Kopikowa, Z., 1987. Remarks on palynostratigraphy of the Quaternary (in Polish with English summary). Kwartalnik Geologiczny, **31**: 155–162.

Janczyk-Kopikowa, Z., 1991. The Ferdynandów Interglacial in Poland. Geological Quaterly, **35**: 71–79.

Jankovská, V., Komárek, J., 2000. Indicative value of *Pediastrum* and other coccal green algae in palaeoecology. Folia Geobotanica, **35**: 59–82.

Juggins, S., 2022. riojaPlot: Stratigraphic diagrams in R, package version 0.1-20; https://github.com/nsj3/riojaPlot

Karaszewski, W., Rühle, E., 1976. Interglacial deposits in western part of Biała Podlaska and Chełm voivodship and in adjoining part of Polesie (in Polish with English summary). Przegląd Geograficzny, **48**: 263–274.

Kats, N.Ya., Kats, S.V., Kipiani, M.G., 1965. Atlas and keys of fruits and seeds occurring in the Quaternary deposits of the USSR (in Russian). Izdatel'stvo Nauka, Moskva.

Kirkham, J.D., Hogan, K.A., Larter, R.D., Arnold, N.S., Ely, J.C., Clark, C.D., Self, E., Games, K., Huuse, M., Stewart, M.A., Ottesen, D., Dowdeswell, J.A., 2024. Tunnel valley formation beneath deglaciating mid-latitude ice sheets: observations and modeling. Quarternary Science Reviews, **323**, 107680; https://doi.org/10.1016/j.quascirev.2022.107680

Koutsodendris, A., Müller, U.C., Pross, J., Brauer, A., Kotthoff, U., Lotter, A.F., 2010. Vegetation dynamics and climate variability during the Holsteinian interglacial based on a pollen record from Dethlingen (northern Germany). Quaternary Science Reviews, **29**: 3298–3307; https://doi.org/10.1016/j.quascirev.2010.07.024

Krupiński, K.M., 1988. Plant succession of the Biała Podlaska (in Polish with English summary). Przegląd Geologiczny, **36**: 647–655.

Krupiński, K.M., 2000. Palynostratigraphic correlation of deposits of the Mazovian Interglacial of Poland (in Polish with English summary). Prace Państwowego Instytutu Geologicznego, **169**.

Krzemińska, E., Krzemiński, L., Petecki, Z., Wiszniewska, J., Salwa, S., Żaba, J., Gaidzik, K., Williams, I.S., Rosowiecka, O., Taran, L., Johanson, A., Peckay, Z., Demaiffe, D., Grabowski, J., Zieliński, G., 2017. Geological map of crystalline basement in the Polish part of the East European Platform, 1:1000 000. Polish Geological Institute – NRI, Warszawa.

Krzywiec, P., 2007. Lublin area (SE Poland) – new views based on results of seismic data inpretation (in Polish with English summary). Biuletyn Państwowego Instytutu Geologicznego, **422**: 1–18.

Kucharska, M., 2023a. Szczegółowa Mapa Geologiczna Polski w skali 1:50 000, arkusz Orzechów Nowy (715) (in Polish). CAG PIG-PIB, Warszawa, nr 10806/2025.

Kucharska, M., 2023b. Objaśnienia do Szczegółowej Mapy Geologicznej Polski w skali 1:50 000, arkusz Orzechów Nowy (715) (in Polish). CAG PIG-PIB, Warszawa, nr 10806/2025.

Kucharska, M., Krawczyk, M., Hrynowiecka, A., 2024. Evolution of the hydrographic network in the middle Wieprz River Basin (E Poland). Geological Quaterly, **68**, 15; https://doi.org/10.7306/gq.1743

Lilpop, J., 1925a. Flora międzylodowcowa spod Włodawy nad Bugiem (in Polish). Posiedzenia Naukowe Państwowego Instytutu Geologicznego, **3**: 1–2.

Lilpop, J., 1925b. Flora międzylodowcowa nad średnim Bugiem (in Polish). Posiedzenia Naukowe Państwowego Instytutu Geologicznego, **11**: 9–10.

Lindner, L., 1988. Outline of Pleistocene stratigraphy of Biała Podlaska region (Eastern Poland) and attempt of correlation with neighboring area of the Soviet Union (in Polish with English summary). Przegląd Geologiczny, **36**: 637–647.

Lindner, L., 1996. Pomazovian glacial and fluvioglacial deposits in the Biała Podlaska region and their age in the light of the discussion on the problem of Warta glaciation in Poland (in Polish with English summary). Biuletyn Państwowego Instytutu Geologicznego, **373**: 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 (in Polish with English summary). Przegląd Geologiczny, **53**: 145–150.

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

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

Lindner, L., 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., Marks, L., 2015. Early and Middle Pleistocene fluvial series in northern foreland of the Carpathians (Poland and Ukraine) and their relation to Dniestr River terraces. Quaternary International, **357**: 22–32; https://doi.org /10.1016/j.quaint.2014.09

Lindner, L., Szymanek, M., 2018. Evolution of Early and Middle Pleistocene river valley systems in Polish, Ukraine-Belarus cross-border areas based on geological and malacological proxies. Geological Quarterly, **62**: 620–630; https://doi.org/10.7306/sq.1426

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

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

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

Lindner, L., Krupiński, K.M., Marciniak, B., Nitychoruk, J., Skompski, S., 1991. Pleistocene lake sediments of the site

Hrud I near Biała Podlaska (in Polish with English summary). Geological Quarterly, **35**: 337–362.

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

Lindner, L., Bogutsky, A., Gozhik, P., Marks, L., Łanczont, M., Wojtanowicz, J., 2006. Correlation of Pleistocene depos its in the area between the Batlic and Black Sea, Central Europe. Geological Quarterly, **50**: 195–210.

Lindner, L., Bogucki, A., Chlebowski, R., Gozik, P., Jełowiczewa, J., Wojtanowicz, J., Zalesski, I., 2007. Quaternary stratigraphy in the Volhynian Polesie (NW Ukraine) (in Polish with English summary). Annales Universitatis Mariae Curie-Skłodowska Sec. B, **62**: 7–41.

Litt, T., Behre, K.E., Meyer, K.D., Stephan, H.J., Wansa, S., 2007. Stratigraphische Begriffe für das Quartär des norddeutschen Vereisungsgebietes. E G. Quaternary Science Journal, **56**: 7–65.

Łanczont, M., Bogucki, A., Yatsyshyn, A., Terpiłowski, S., Mroczek, P., Orłowska, A., Hołuba, B., Zieliński, P., Komar, M., Woronko, B., Kulesza, P., Dmytruk, R., Tomeniuk, O., 2019. Stratigraphy and chronology of the periphery of the Scandinavian ice sheet at the foot of the Ukrainian Carpathians. Palaeogeography, Palaeoclimatology, Palaeoecology, **530**: 59–77; https://doi.org/10.1016/j.palaeo.2019.05.024

Łozińska-Stępień, H., Rytel, A., Saliński, P., 1985. Objaśnienia do Szczegółowej Mapy Geologicznej Polski 1:50 000, arkusz Lubartów (713) (in Polish). CAG PIG, Warszawa, nr 10081/2025.

Małek, M., Pidek, A., 2007. Palinostratigraphy of organogenic depos its of new interglacial stands on the Łuków Plain (in Polish with English summary). Annales Universitatis Mariae Curie-Skłodowska Sec. B, **62**: 43–57.

Marr, K.L., Allen, G.A., Hebda, R.J., McCormick, L.J., 2013. Phylogeographical patterns in the widespread arctic-alpine plant *Bistorta vivipara* (Polygonaceae) with emphasis on western North America. Journal of Biogeography, **40**: 847–856; https://doi.org/ 10.23307/23463603

Marks, L., 2023a. Pleistocene glaciations in southern Poland – a revision. Geological Quarterly, **67**, 25; https://doi.org/1010.24425/agp.2023.145614

Marks, L. (ed.), 2023b. Geological map of Polish-Belarusian-Ukrainian border area, Włodawa region 1:250,00. Polish Geological Institute – NRI, Warszawa.

Marks, L., Pavlovskaja, I.E., 2006. Correlation of the Saalian glacial limits in eastern Poland and western Belarus. Quaternary International, **149**: 87–93; https://doi.org/ 10.1016/j.quaint.2005.11.021

Marks, L., Dzierżek, J., Janiszewski, R., Kaczorowski, J., Lindner, L., Majecka, A., Makos, M., Szymanek, M., Tołoczko-Pasek, A., Woronko, B., 2016. Quaternary stratigraphy and palaeogeography of Poland. Acta Geologica Polonica, **66**: 403–427; https://doi.org/10.1515/agp-2016-0018

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., Pielach, M., 2018. Revised limit of Saalian ice sheet in central Europe. Quaternary International, **478**: 59–74; https://doi.org/10.1016/j.quaint.2016.07.043

Marks, L., Pochocka-Szwarc, K., Żarski, M., Hrynowiecka, A., Orłowska, A., 2024. Late Pleistocene nival deposits in the western part of Polesie (Polish Belarusian-Ukrainian border area) (in Polish with English summary). Przegląd Geologiczny, **72**: 490–500; https://doi.org/10.7306/2024.30

Marszałek, S., 2000. Objaśnienia do Szczegółowej Mapy Geologicznej Polski w skali 1:50 000, arkusz Włodawa (681) (in Polish). CAG PIG, Warszawa, nr 88703.

Marszałek, S., 2001. Szczegółowa Mapa Geologiczna Polski w skali 1:50 000, arkusz Włodawa (681) (in Polish). CAG PIG, Warszawa, nr 88703.

Maruszczak, H., 1966. Phenomènes karstiques dans les roches du crétacé supérieur entre la Vistule et le Bug (Type de karst crayeux) (in Polish with French summary). Przegląd Geograficzny, **38**: 339–370.

Maruszczak, H., 2001. Relief development in the eastern part of the Meta-Carpathian Uplands during the post-Sarmatian period (in Polish with English summary). Przegląd Geograficzny, **73**: 253–280.

Mazur, S., Krzywic, P., Malinowski, M., Lewandowski, M., Aleksandrowski, P., Mikołajczyk, M., 2017. Tectonic significance of the Teisseyre-Tornquist zone in the light of new research (in Polish with English summary). Przegląd Geologiczny, **65**: 1511–1520.

Mojski, J.E., 1964. Oldest Pleistocene formations in the Wieprz river valley near Krasnystaw (in Polish with English summary). Kwartalnik Geologiczny, **8**: 326–341.

Mojski, J., Trembaczowski, J., 1961. Geologic cross-section of Quaternary deposits at Suszno near Włodawa on the Bug River (in Polish with English summary). Biuletyn Instytutu Geologicznego, **169**: 131–153.

Moore, P.D., Webb, J.A., Collinson, M.E., 1991. Pollen Analysis. Blackwell, London.

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

Narkiewicz, M., 2003. Tectonic controls of the Lublin Graben (Late Devonian-Carboniferous) (in Polish with English summary). Przegląd Geologiczny, **51**: 771–776.

Narkiewicz, M., Jarosiński, M., Krzywiec, P., Waksmundzka, M., 2007. Regional controls on the Lublin Basin development and inversion in the Devonian and Carboniferous (in Polish with English summary). Biuletyn Państwowego Instytutu Geologicznego, **422**: 19–33.

Nita, M., 2009. Pollen stratigraphy and vegetation history during the Mazovian Interglacial and the older part of Liviecian Glaciation in the western and central part of Polish Uplands (in Polish with English summary). Prace Naukowe Uniwersytetu Śląskiego, **2658**.

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., Bińka, J., Hoefs, J., Ruppert, H., Schneider, J., 2005. Climate reconstruction for the Holsteinian Interglacial in eastern Poland and its comparison with isotopic data from Marine Isotope Stage 11. Quaternary Science Reviews, **24**: 631–644; https://doi.org/10.1016/j.quascirev.2004.07.023

Obarska, E., 1996. Wyniki badań palinologicznych próbek osadów z profili Różanka i Włodawa (in Polish). CAG PIG, Warszawa, nr 88703.

Orłowska, A., Marks, L., Rychel, J., Pochocka-Szwarc, K., Żarski, M., Hrynowiecka, A., Nowacki, Ł., Bogucki, A., Zalesskyi, I., Tomeniuk, O., Moska, P., 2025. Middle Pleistocene (MIS 12) deglaciation in the border region of Poland, Ukraine and Belarus: new approach in the Quaternary of central-eastern Europe. Quaternary International, QUATINT-D-25-00220R2.

Pidek, I.A., 2003. Mesopleistocene vegetation history in the northern foreland of the Lublin upland based on palaeobotanical studies of the profiles from Zdany and Brus sites. Wydaw. Universitatis Mariae Curie-Skłodowska.

Pidek, I.A., 2015. Palynostratigraphy and vegetation changes during the early Middle Pleistocene, based on new studies of deposits from Ferdynandów (central eastern Poland). Acta Palaeobotanica, **55**: 53–66; https://doi.org/10.1515/acpa-2015-0002

Pidek, I.A., Małek, M., 2010. A bi-partite Ferdynandovian succession from Łuków, Eastern Poland: a new palynostratigraphic approach. Geological Quarterly, **54**: 69–84.

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

Pidek, I.A., Stachowicz-Rybka, R., Żarski, M., 2015. New palaeobotanical data from the Ferdynandów 2011 profile in the stratotype site (in Polish with English summary). Annales Universitatis Mariae Curie-Skłodowska Sec. B, **70**: 9–26.

Pochocka-Szwarc, K., 2023a. Szczegółowa Mapa Geologiczna Polski w skali 1:50 000, arkusz Kołacze (716) (in Polish). CAG PIG-PIB, Warszawa, nr 10814/2025.

Pochocka-Szwarc, K., 2023b. Szczegółowa Mapa Geologiczna Polski w skali 1:50 000, arkusz Sosnowica (679) (in Polish). CAG PIG-PIB, Warszawa, nr 10801/2025.

Pochocka-Szwarc, K., 2023c. Objaśnienia do Szczegółowej Mapy Geologicznej Polski w skali 1:50 000, arkusz Sosnowica (679) (in Polish). CAG PIG-PIB, Warszawa, nr 10801/2025.

Pochocka-Szwarc, K., 2023d. Objaśnienia do Szczegółowej Mapy Geologicznej Polski w skali 1:50 000, arkusz Kołacze (716) (in Polish). CAG PIG-PIB, Warszawa, nr 10814/2025.

Pochocka-Szwarc, K., Żarski, M., 2023. Geological map of Polish-Belarusian-Ukrainian border area. Włodawa region 1:250 000 (ed. L. Marks). Polish Geological Institute – NRI, Warszawa.

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

Pochocka-Szwarc, K., Żarski, M., Hrynowiecka, A., Górecki, A., Pidek, I.A., Szymanek, M., Stachowicz-Rybka, R., Stachowicz, K., 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. Geological Quarterly, **68**, 18; https://doi.org/10.7306/gq.1746

Pochocka-Szwarc, K., Żarski, M., Górecki, A., Orłowska, A., Hrynowiecka, A., Skoczylas-Śniaz, S., Stachowicz-Rybka, R., Stachowicz, K., 2025a. Evidence for the presence of the Sanian 2 Glaciation (Elsterian, MIS 12) ice-sheet, a case study of palaeobasins from the Mazovian Interglacial (Holsteinian, MIS 11c) and terrain relief in Wantopol site (Western Polesie, E Poland). Acta Geologica Polonica, **75**, e57; https://doi.org/10.24425/agp.2025.155951

Pochocka-Szwarc, K., Żarski, M., Tekielska, A., 2025b. Mapa Geologiczna Polski w skali 1:200 000, arkusz Włodawa, mapa A (in Polish). CAG PIB, Warszawa.

Posit team, 2025. RStudio: Integrated Development Environment for R. Posit Software, PBC, Boston, MA. http://www.posit.co/

Reille, M., 1992. Pollen et Spores d'Europe et d'Afrique du Nord. Laboratoire de Botanique Historique et Palynologie. Marseille, France.

Richling, A., Solon, J., Macias, A., Balon, J., Borzyszkowski, J., Kistowski, M. (eds.), 2021. Regionalna geografia fizyczna Polski (in Polish). Bogucki Wydaw. Naukowe, Poznań.

Rühle, E., 1936. Ślady dwóch zlodowaceń nad Prypecią (in Polish). Czasopismo Geograficzne, **14**: 79–83.

Rychel, J., Orłowska, A., Zbucki, Ł., Nowacki, Ł., Zalesskij, I., 2021. Revised palaeogeography and stratigraphy of the Rostan hills in north-western Ukraine. Studia Quaternaria, **38**: 33–41; https://doi.org/10.24425/sq.2020.133757

Rzechowski, J., 1996. The Ferdynandowian Interglacial and its stratigraphical position in the Middle Pleistocene of Europe. In: The Early Middle Pleistocene in Europe (ed. Ch. Turner): 279–293. Balkena, Rotterdam.

Sawicki, L., 1922. Wiadomość o środkowopolskiej morenie czołowej (in Polish). Rozprawy PAU A, **61**: 1–42.

Stachowicz-Rybka, R., Pidek, A.I., Żarski, M., 2017. New palaeoclimate reconstructions based on multidisciplinary investigation in the Ferdynandów 2011 stratotype site (eastern Poland). Geological Quarterly, **61**: 276–290; https:// doi.org/10.7306/gq.1353

Stachurska, A., 1955. *Pterocarya* from the interglacial deposits of Włodawa (in Polish with English summary). Acta Societatis Botanicorum Poloniae, **24**: 567–569.

Stachurska, A., 1957. Interglacial flora from Włodawa on the Bug River (Lublin Upland) (in Polish with English summary). Biuletyn Instytutu Geologicznego, **118**: 85–89.

Stachurska, A., 1960. *Keteleeria* w osadach interglacjalnych z Suszna nad Bugiem (in Polish). Przegląd Geologiczny, **8**: 283.

Stachurska, A., 1961. Decline of the Mazovian interglacial at Suszno near Włodawa on the Bug river in the light of botanical analysis (in Polish with English summary). Biuletyn Instytutu Geologicznego, **169**: 155–173.

Szymanek, M., 2011. Climate oscillations of the Holsteinian (Mazovian) Inter glacial recorded in shell morphometry of *Viviparus diluvianus* (Kunth, 1865) from eastern Poland. Quaternary International, **241**: 143–159; https://doi.org/10.1016/j.quaint.2010.04.003

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

Szymanek, M., 2013. Palaeoecology of the Holsteinian lake in vicinity of Wilczyn (Eastern Poland) based on molluscan studies. Geological Quarterly, **57**: 637–648; https://doi.org/10.7306/gq.1120

Szymanek, M., 2014. Environmental changes of the Mazovian (Holsteinian/~MIS 11) palaeolake near Szymanowo (eastern Poland) in the light of malacological analysis. Acta Geologica Polonica, **64**: 249–260; https://doi.org/10.2478/agp-2014-0013

Szymanek, M., Nitychoruk, J., Trammer, J., Bińka, K., 2005. Influence of climate on the variability of snails of the genus *Viviparus* in deposits of the Holsteinian (Mazovian) Interglacial from Ortel Królewski, eastern Poland. Boreas, **34**: 335–344; https://doi.org/10.1111/j.1502-3885.2005.tb01105.x

Terpiłowski, S., Zieliński, T., Kusiak, J., Pidek, I.A., Czubla, P., Hrynowiecka, A., Godlewska, A., Zieliński, P., Małek, M., 2014. How to resolve Pleistocene stratigraphic problems by different methods? A case study from eastern Poland. Geological Quarterly, **58**: 235–250; http://doi.org/10.7306/gq.1158

Terpiłowski, S., Zieliński, T., Mroczek, P., Zieliński, P., Czubla, P., Fedorowicz, S., 2021. New evidence for the rank of the Wartanian cold period (Pleistocene, MIS 6): a case study from E Poland. Annales Societatis Geologorum Poloniae, **91**: 327–345; https://doi.org/10.14241/asgp.2021.20

Trembaczowski, J., 1957. Quaternary formations in the vicinity of Włodawa (Eastern Poland) (in Polish with English summary). Biuletyn Instytutu Geologicznego, **118**: 343–369.

Trembaczowski, J., 1963. Stratygrafia utworów czwartorzędowych okolic Włodawy (in Polish). Materiały Sesji Naukowej Polskiego Towarzystwa Geologicznego (red. T. Wilgata). Wydaw. Lubelskie, Lublin.

Trembaczowski, J., 1965. Objaśnienia do Szczegółowej Mapy Geologicznej Polski w skali 1:50 000, arkusz Kaplonosy (680) (in Polish). CAG PIB, Warszawa, nr 859/2004.

Trembaczowski, J., 1968. Szczegółowa Mapa Geologiczna Polski w skali 1:50 000, arkusz Kaplonosy (680) (in Polish). CAG PIB, Warszawa, nr 859/2004.

Tutkovsky, P.A., 1901. Koniechnyye moreny, valunyya polosy i ozy v yuzhnom Polesiye s kartoy (in Russian). **57**: 353–460. Zapiski Kiyevskogo Obshchestva Estestvoispytateley, 17. Kiyev.

Tutkovsky, P.A., 1904. Piashchannye ozy w Kiyevskoy i Volynskoy guberniyakh (in Rusian). Zapiski Kiyevskogo Obshchestva Estestvoispytateley, 18. Kiyev.

Velichkevich, F.Yu., Zastawniak, E., 2006. Atlas of Pleistocene vascular plant macroremains of Central and Eastern Europe, Part I – *Pteridophyte*s and *monocotyledons.* W. Szafer Institute of Botany, Polish Academy of Sciences, Krakow.

Velichkevich, F.Yu., Zastawniak, E., 2008. Atlas of vascular plant macroremains from the Pleistocene of central and eastern Europe, Part II – *Herbaceous dicotyledons*. W. Szafer Institute of Botany, Polish Academy of Sciences, Krakow.

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

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

Wojtanowicz, J., 1993. Lithology and stratigraphy of the Pleistocene sediments in the Bug River Valley near Uhrusk (in Polish with English summary). Annales Universitatis Mariae Curie-Skłodowska Sec. B, **48**: 298–309.

Wojtanowicz, J., 1994a. The Warta Glaciation deposits within the non-glaciated zone in the Polesie Lubelskie (in Polish with English summary). Acta Geographica Lodzensis, **65**: 111–125.

Wojtanowicz, J., 1994b. On thermokarst genesis of the Łęczna--Włodawa lakes (in Polish with English summary). Annales Universitatis Mariae Curie-Skłodowska Sec. B, **49**: 1–18.

Wyrwicka, K., Wyrwicki, R., 1986. Geological cross-section through the Uhrusk Arc (in Polish with English summary). Kwartalnik Geologiczny, **30**: 629–642.

Zaborski, B., 1927. Studia nad morfologią dyluwium Polesia i terenów sąsiednich (in Polish). Przegląd Geograficzny, **7**: 1–52.

Zając, A., Zając, M. (eds.), 2001. Distribution Atlas of Vascular Plants in Poland. Institute of Botany, Jagiellonian University, Kraków.

Żarski, M., Morawski, M., 2018. Szczegółowa Mapa Geologiczna Polski 1:50 000, arkusz Kaplonosy (680) (in Polish). CAG PIG-PIB, Warszawa, nr 1390/2013.

Żarski, M., Morawski, M., 2019. Objaśnienia do Szczegółowej Mapy Geologicznej Polski w skali 1:50 000, arkusz Kaplonosy (680) (in Polish). CAG PIG-PIB, Warszawa, nr 1390/2013.

Żarski, M., Pochocka-Szwarc, K., 2025. Objaśnienia do Mapy Geologicznej Polski w skali 1:200 000, arkusz Włodawa (in Polish). CAG PIG-PIB, Warszawa.

Żarski, M., Małek, M., Albrycht, A., 2009. Plejstocen południowego Podlasia (in Polish). In: Strefa marginalna lądolodu zlodowacenia warty i pojezierza plejstoceńskie na południowym Podlasiu (eds. M. Żarski and W. Lisicki): 20–36. Państwowy Instytut Geologiczny, Warszawa.

Żarski, M., Pochocka-Szwarc, K., Orłowska, A., Hrynowiecka, A., 2023. The site of Suszno on the Bug River (in Polish with English summary). In: Geological map of Polish-Belarusian--Ukrainian border area. Włodawa region, scale 1:250 000 (ed. L. Marks): 97–94. Państwowy Instytut Geologiczny – PIB, Warszawa.

Żarski, M., Hrynowiecka, A., Górecki, A., Winter, H., 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**, 14; https://doi.org/10.24425/agp.2024.150006

Żelichowski, A.M., 1972. Evolution of the geological structure of the area between the Góry Świętokrzyskie and the river Bug (in Polish with English summary). Biuletyn Instytutu Geologicznego, **263**: 1–97.

Żelichowski, A.M., 1974. Obszar radomsko-lubelski (in Polish). In: Budowa Geologiczna Polski, **4**. Tektonika (ed. W. Pożaryski): 113–127. Wydaw. Geol., Warszawa.

Żelichowski, A.M., 1984. Tektonika Lubelskiego Zagłębia Węglowego (in Polish). In: Przewodnik 56. Zjazdu Polskiego Towarzystwa Geologicznego: Zagadnienia geologii, hydrogeologii, ochrony środowiska i złóż Lubelszczyzny (ed. M. Harasimiuk). Wydaw. Geol., Warszawa.