Quaternary Research 77 (2012) 492–499

Contents lists available at SciVerse ScienceDirect

Quaternary Research

journal homepage: www.elsevier.com/locate/yqres

Malacological and palynological evidence of the Lower Pleistocene cold phase at the Carpathian Foothills (Southern Poland)

Ewa Stworzewicz [a,*], Wojciech Granoszewski [b], Antoni Wójcik [b]

[a] Institute of Systematics and Evolution of Animals, Polish Academy of Sciences, Sławkowska 17, 31–016 Kraków, Poland
[b] Polish Geological Institute, National Research Institute, Carpathian Branch, Skrzatów 1, 31–560 Kraków, Poland

ARTICLE INFO

Article history:
Received 7 July 2011
Available online 23 March 2012

Keywords:
Lower Pleistocene
Cold phase
Land snails
Pollen analysis
Carpathian Foothills

ABSTRACT

Early Pleistocene sediments bearing gastropod shells and pollen flora were found during coring at Jawornik (South Poland) at a depth interval of 54.30–39.00 m, beneath the oldest till of the Carpathians. Thirteen land-snail taxa identified in 55 samples of the core formed two molluscan assemblages. In the bottom part, typical cold-loving snails were found (e.g. *Vallonia tenuilabris*, *Pupilla loessica*, *Vertigo genesii*, *Columella columella*), whereas in the upper part only *Semilimax kotulae* was present. The succession of molluscan assemblages may suggest that at the site of deposition, after a phase of tundra, steppe-tundra or forest-steppe landscape with patches of wet habitats in cold climate, the climate became slightly milder but still cool, favourable to the spreading of boreal (coniferous) woodlands. Pollen analysis was performed only for the upper part of the profile. The pollen spectra, besides the Tertiary (Miocene) elements, contained sporomorphs common to the Tertiary and Quaternary floras. Among them, the highest percentages were noted for *Pinus haploxylon* t., *P. diploxylon* t., *Picea*, *Quercus*, *Ericaceae*, *Betula*, and *Ulmus*. The fact that the sediments with organic remains underlie the oldest Scandinavian till suggests that they are older than the oldest glacial unit of the South-Polish Complex (Narevian = Menapian, ~1.2 Ma).

Introduction

Mollusc- and flora-bearing organic sediments were found during coring for the Detailed Geological Map of Poland, 1:50 000 Strzyżów sheet (Malata, 2009), at Jawornik (21°47′E, 49°52′N) (Figs. 1 and 2). Gastropod shells and pollen flora were located at the depth interval of 54.50–39.00 m, underlying the oldest Scandinavian glaciation till deposit in the Carpathians. The age of this till has been a matter of dispute from quite a long time. Actually, there are four glaciations within the South-Polish Complex containing the oldest Pleistocene glaciations in Poland — Narevian, Nidanian, Sanian 1 and Sanian 2 (Ber, 2005; Ber et al., 2007; Lindner and Marks, 2008). Until recently the Sanian 1 (~0.65 Ma) glaciation was considered the only which invaded the Capathians Mts. According the newest paleomagnetic data from Kończyce profile located at the Carpathians border the oldest till should be associated with the Narevian (= Manepian, ~1.2 Ma) glaciation (Wójcik et al., 2004; Foltyn et al., 2010).

The present paper reconstructs local paleoenvironment changes during the Lower Pleistocene in the Carpathian Foothills based on mollusc assemblages and vegetation from the Jawornik core.

Mollusc assemblages indicative of cold or cool climatic condition are very common in the late Pleistocene deposits of central Europe, but data from the older Pleistocene sections are comparatively scarce. The oldest locality bearing some cold-loving species comes from the upper Pliocene at Stranzendorf in Austria (Frank, 2006), and a few early Pleistocene localities were noted from Krems and Radlbrunn in Austria, from Červený kopec (former Czechoslovakia) (Ložek, 1964) and from several sites in Germany (Mania, 1973). In Hungary, some of the cold-tolerant species are known only starting with the middle Pleistocene (*V. tenuilabris*, *V. alpestris*), but they are mainly recorded from late Pleistocene sediments (Krolopp and Sümegi, 1993; Fűköh et al., 1995).

In Poland, the oldest (loess) sediments bearing cold-loving species such as *Vallonia tenuilabris*, *Columella columella* and *Vertigo parcedentata* have been recorded from the Świętokrzyskie Mts. (Poliński, 1927) (Fig. 2) and correlated to the Sanian 1 glaciation (~0.65 Ma) (= Sanian: Skompski, 1996). Much more information has been provided by early Pleistocene interglacial deposits from Kielniki 3A (Stworzewicz, 1981), dated as Lower Biharian (1.4–1.5 Ma) in mammal stratigraphy (Nadachowski, 1990) and containing numerous species of warm-humid, deciduous or mixed forest snails, including some Tertiary taxa which survived up to the early Pleistocene.

Lower Pleistocene (pre-glacial) pollen records from the territory of Poland are rather scarce and fragmentary. Most of them come from central Poland (Mamakowa, 2003). In the Carpathians, only one locality with lacustrine sediments has been analyzed for pollen

* Corresponding author. Fax: +48 12 422 42 94.
E-mail address: stworzewicz@isez.pan.krakow.pl (E. Stworzewicz).

0033-5894/$ – see front matter © 2012 University of Washington. Published by Elsevier Inc. All rights reserved.
doi:10.1016/j.yqres.2012.02.006

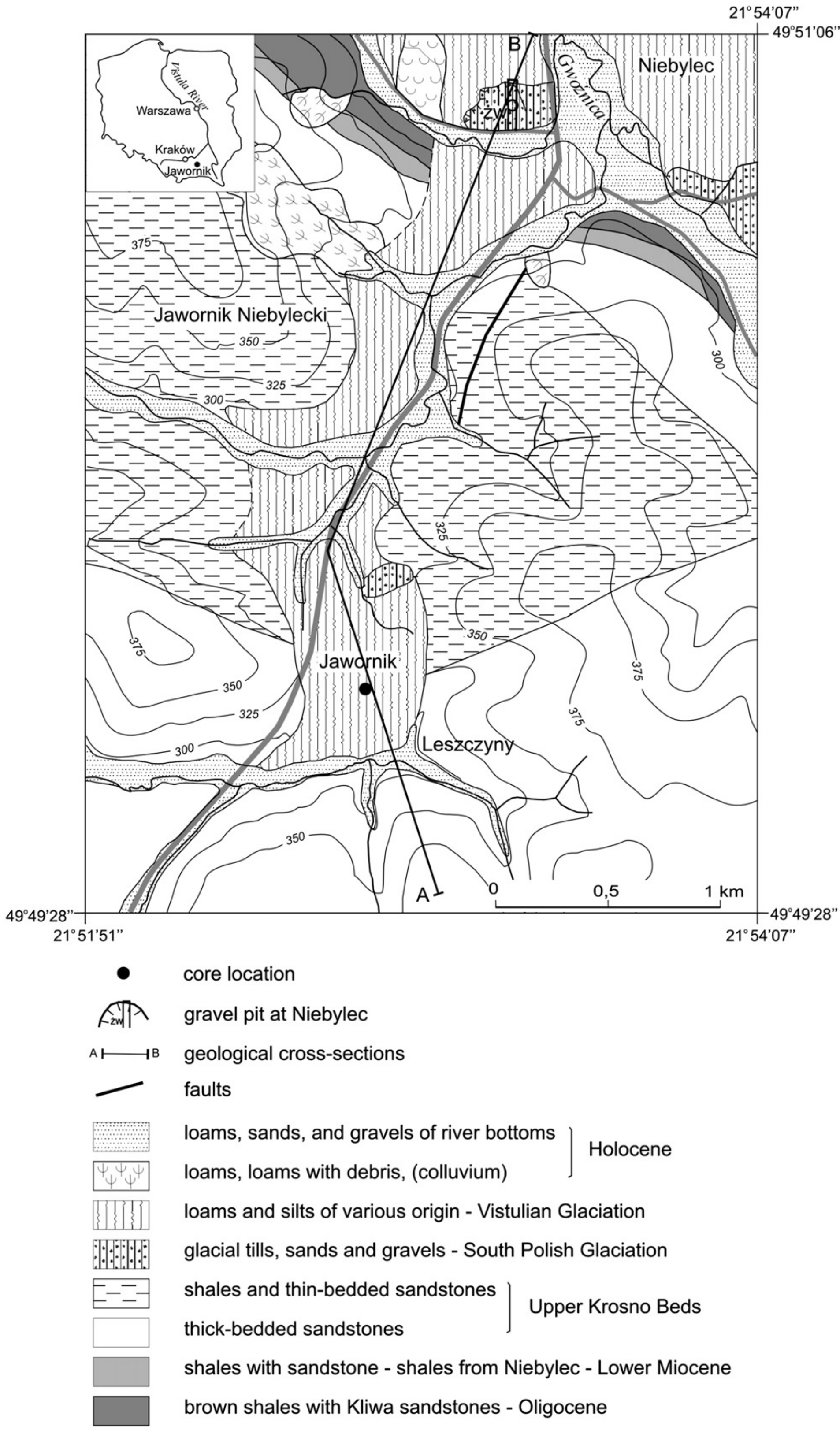
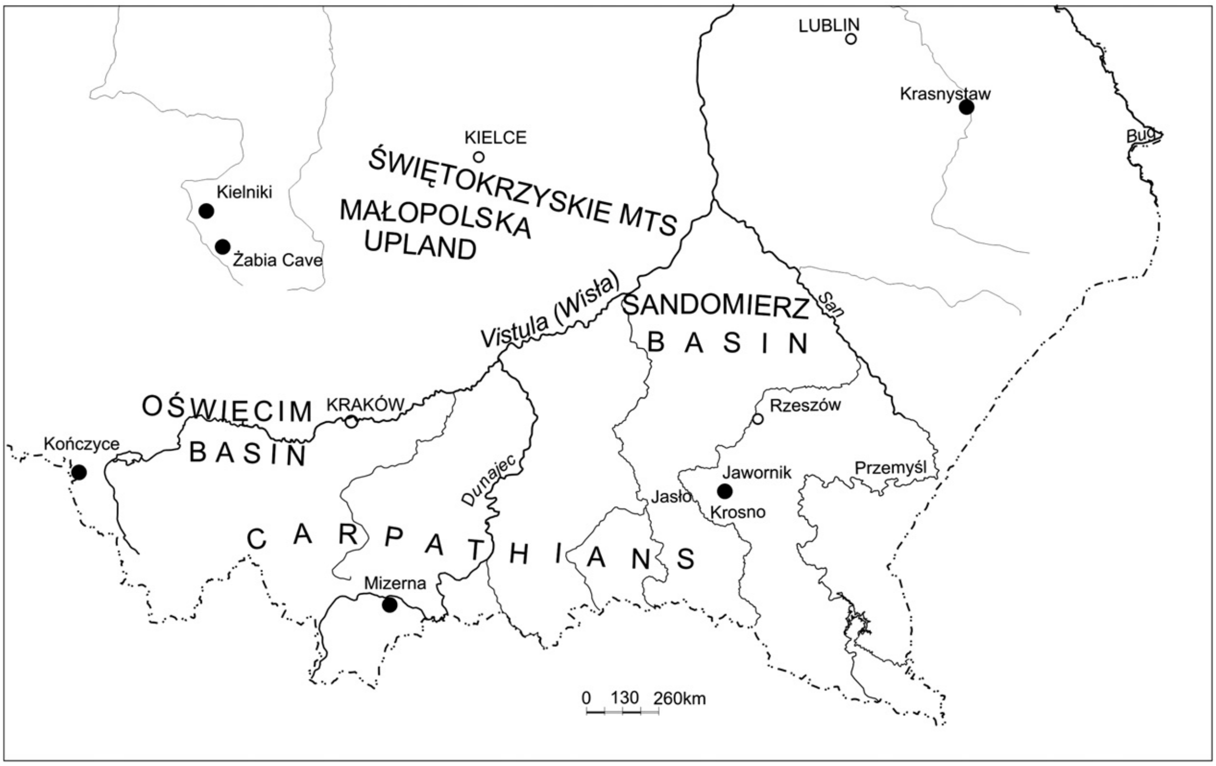


Figure 1. Location of the study area in the Detailed Geological Map of Poland (after Malata, 2009). Elevation contours (25-m increments) are given in m a.s.l.

and plant macrofossils (Szafer, 1954). The pollen succession from site Mizerna near Czorsztyn (Fig. 2) comprises several climatic phases: Dacian, Reuverian, Praetiglian, Tiglian, Eburonian, and Wallian (~5.3–1.3 Ma) (Zagwijn, 1985; Stuchlik, 1994). According to Szafer (1954) and Stuchlik (1994) the Reuverian/Praetiglian boundary is recorded in the profile from Mizerna, where it is marked by the decline of the Tertiary pollen elements as well as by the decline of the Quaternary taxa with higher climatic demands, mainly broadleaved trees. Although the Jawornik core contained only a sparse fossil record, the molluscs and pollen recovered from it nevertheless extend

https://doi.org/10.1016/j.yqres.2012.02.006 Published online by Cambridge University Press



Location of the sites mentioned in the text

Figure 2. Location of the sites containing the flora and malacofauna remains mentioned in the text.

our understanding of early Pleistocene conditions in the Carpathian foothills.

Material and methods

The Jawornik core, 112 mm in diameter, was 55 m long. Only the old Pleistocene portion of the core from 32 m downwards containing the till and underlying organic sediments was worthy of further investigation (Table 1). Samples for paleontological studies were taken regularly at 20–50 cm intervals beneath the glacial till (Fig. 3). Only a segment 15.30 m long contained gastropod remains. An even-shorter core segment, 10 m long, contained flora remnants, and only 3.5 m of that contained recoverable pollen. Samples with shells were wetted and sieved on 0.25-mm mesh under running water. The sieve remains were dried and gastropod shells or their identifiable fragments were extracted. The material was not rich; in general the number of shells per sample ranged from several to over a dozen.

Sediment samples for pollen analysis were treated with 15% HCl and then boiled with 10% KOH. The mineral fraction was separated using flotation method ($ZnCl_2$, 1.88–2.00 g/cm^3). The organic fraction was subject to Erdtman's acetolysis and mounted in pure glycerine. Pollen concentration in the sediments was very low, and the counted pollen sums varied from 50 to 250 pollen grains. Preservation of the sporomorphs was poor or very poor.

Table 1
Sediments in the Jawornik core.

Depth, m	Sediment type
00.0–6.9	Yellow silt (loess)
6.9–34.5	Loams, sands, and glacial gravel
34.5–38.7	Lodgement till
38.7–39.0	Grey silt with light-grey sandy silt
39.0–39.95	Grey silt, weakly laminated
39.95–40.8	Grey silt with plant remains
40.8–42.4	Grey sandy silt
42.4–43.5	Grey sandy silt with organic remains
43.5–49.0	Grey silt with muscovite, weakly laminated
49.0–50.2	Grey silt with small black organic remnants, and irregular lenses of highly lithified sandy silt or clayey sand
50.2–51.55	Beige clayey silt with muscovite, locally laminated and sandy
51.55–51.6	Light-grey clayey sandstone
51.6–52.3	Dark-grey sandy silt with muscovite
52.3–53.3	Greyish-yellow and greenish silt with sand and mollusc shells
53.3–53.35	Weakly lithified sandstone
53.35–54.0	Olive-green sandy silt with lithified sand, weakly laminated
54.0–54.5	Beige silt with lithified sand with mollusc shells
54.5–54.6	Brown and rusty-brown clayey sand (weathered sandstone)
54.6–55.0	Weathered fine-grained yellow-beige sandstone (the Krosno Bed)

Geological setting

The borehole is located in the Strzyżów Foothills area within the limit of the maximum range of the Scandinavian ice sheet (~1.2 Ma), which in some places reached the Jasło-Sanok Depression (Wójcik, 2003; Foltyn et al., 2010). Organic sediments underlying the till deposits have previously not been recognized in the Carpathians. An outcrop situated ~3 km north of the borehole contains glacial sediments, mainly gravel and shingle, gravelly sand, and varved clay at the top (Fig. 4). This nearly 40-m-thick series of glacigenic sediments has been described by Butrym and Gerlach (1985) and Wójcik (1999).

The borehole was made at the altitude of 320 m a.s.l. in the flattened pass located about 60 m below the ridges, which surfaces lie at 380–440 m a.s.l. This area consists of Oligocene–Miocene flysch (Fig. 1) of the Skole Nappe, covered with a thin (1–2 m) layer of weathered deposits. Where the drilling was performed, the depression is only 0.6 km in width. It is filled with Quaternary deposits nearly 55 m thick. They consist of loess, till, and a series of sandy silts more than 15 m thick. These predate the oldest Pleistocene glaciation (Narevian, ~1.2 Ma) (Zagwijn, 1985; Ber, 2005; Ber et al., 2007).

https://doi.org/10.1016/j.yqres.2012.02.006 Published online by Cambridge University Press

Lithology of the core sediments (Figs. 1, 3 and 4)

In the profile from the Jawornik core (Table 1), till overlies a series silts that are poorly differentiated by lithology, and are not glacigenic. The entire series can be divided into a lower part that occurs below the depth of 49 m and is sandier, and an upper part, from the depth of 49 m upwards to the bottom of the glacial deposits. At the depth of about 49 m there is a distinct boundary, marked by changing the colour and lithology.

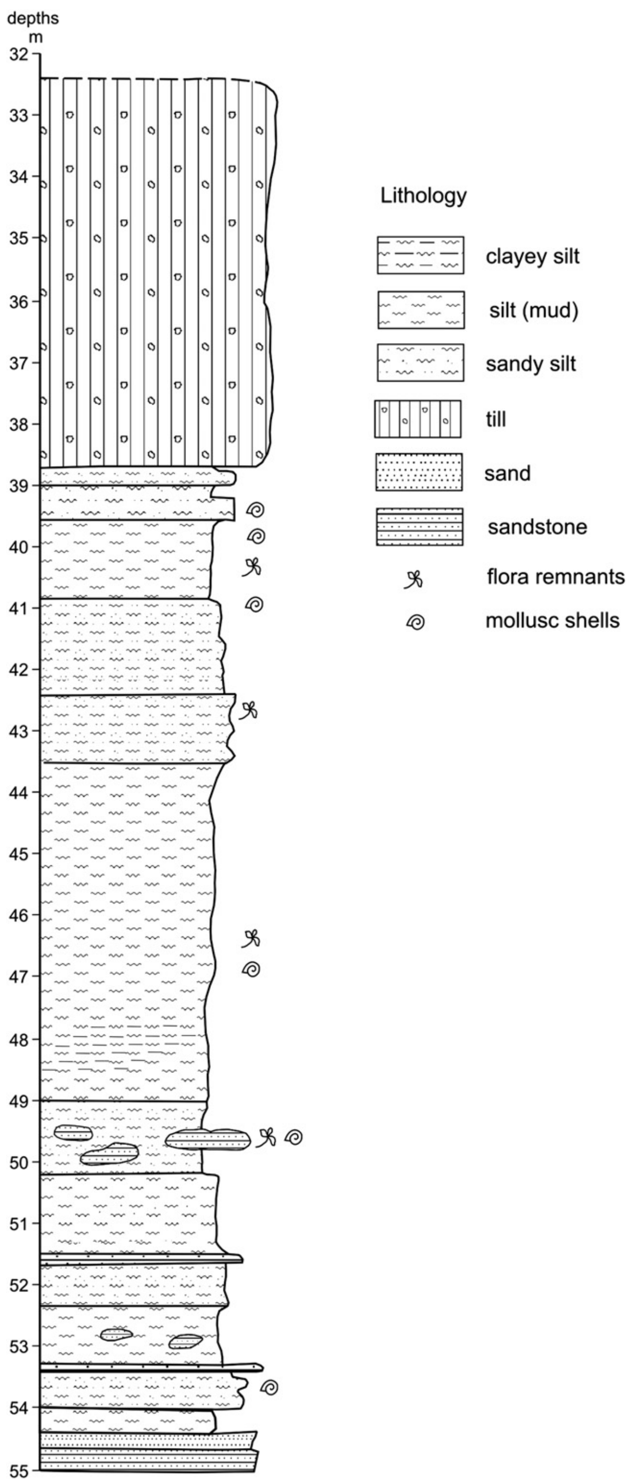


Figure 3. Lithological profile, Jawornik core.

The Jawornik core shows that the bottom of the Quaternary sediments lies below the present river channels in this region (Fig. 4). These sediments were deposited in the bottom of the paleo-valley, the course of which was different from the present one. Similar deposits, underlain by river gravels and sands, have been drilled in two other places.

The Jawornik core sediments show horizontal laminations, indicating a fluvial origin in a low-power stream. The sediments were probably deposited during floods. The stream was likely no bigger than present-day watercourses ('H' in Fig. 4). The thickness of the sediment exceeds 15 m, indicating that the sedimentation must had taken place under subsidence conditions and later tectonically raised. Such a thick fluvial series may have been deposited in the period probably immediately preceding the maximum Pleistocene glaciation, which entered the Carpathians. These sediments can be correlated with the series of Krasnystaw (0.95 – 1.87 Ma) (Mojski, 1985; Lindner, 1992). They are the thickest glacial till covered organic early Pleistocene series yet found in the Carpathians.

Results

Malacological analysis

Thirteen land snail taxa were identified in 55 core samples; they formed two molluscan assemblages (Table 2). The bottom part (54.30–48 m), represented by 21 samples, contained mainly typical cold-loving snails regarded as index glacial species. *Vallonia tenuilabris*, *Pupilla loessica*, *Semilimax kotulae* and *Succinea oblonga elongata* were the most frequent. Some of these species became extinct in Europe at the end of the Pleistocene (*V. tenuilabris*, *P. loessica*); others are still extant either in northern Europe (*Vertigo parcedentata*) or as boreo-alpine elements are distributed in the northern Europe and mountains of central Europe (*Vertigo genesii*, *Columella columella*). Recently all these species were found living in the Russian Altai mountains, Central Asia (Meng and Hoffmann, 2009; Horsák et al., 2010; Hoffmann et al., 2011).

The studied assemblage was complemented by snails which are at present common in Poland (*Pupilla muscorum* and *Vertigo alpestris*), and the elongated form of *Succinea oblonga* (*S. oblonga elongata*). In four samples from the depth interval 50–49 m a few unidentifiable fragments of clausiliid and helicid shells were also found.

In the upper part of core (48–39.50 m) only *Semilimax kotulae* was present in all samples, except for the segment between 43 and 41.50 m that lacked mollusc remains. Besides, *S. kotulae* is the only species that occurs in almost all the samples studied. In Poland, former Czechoslovakia and Hungary *S. kotulae* is known mainly from the Vistulian and early Holocene sediments, but in Austria it was also recorded as early as the late Pliocene (Frank, 2006).

Pollen analysis

Pollen analysis was performed only for the upper part of the profile (46.30–38.90 m). The results are shown as a percentage pollen diagram (Fig. 5). In the lower portion of the profile (50–49 m) the extremely low sporomorph precluded quantitative pollen analysis. The sporomorphs found there are shown in Table 3.

The pollen spectra from the Jawornik profile include sporomorphs of Tertiary age as well as elements that are common to the Tertiary and Quaternary floras. The prevailing Tertiary elements like *Pterocarya*, *Liquidambar*, *Nyssa*, *Tsuga*, *Araliaceae*, *Carya*, *Cyrillaceae*/*Clethraceae*, *Castanea*/*Castanopsis* and many others (Fig. 5) may suggest temperate climate conditions.

The Tertiary pollen was very poorly preserved and very often difficult to identify, for example *Bissacate* pollen grains (Pinaceae). Along with the very low pollen concentration, this suggests its redeposition in the studied sediment. The state of preservation of pollen

https://doi.org/10.1016/j.yqres.2012.02.006 Published online by Cambridge University Press

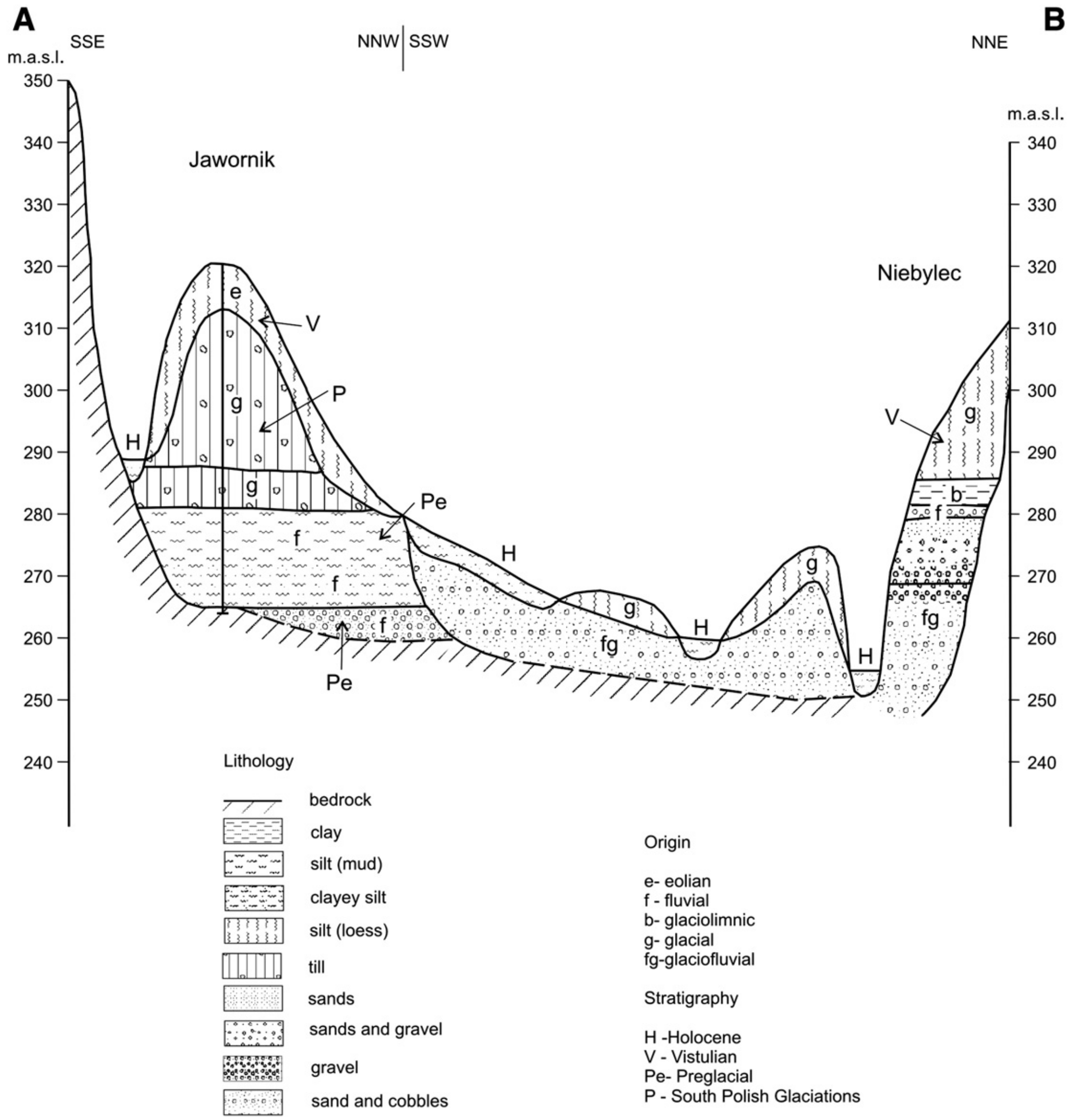


Figure 4. Cross section, Jawornik–Niebylec (location: Figs. 1 and 2). The Jawornik core is shown as a heavy vertical black line.

grains attributed to the Quaternary taxa was significantly better. Among the pollen taxa that are common to both the Tertiary and Quaternary plant communities, the highest percentages were noted for *Pinus haploxylon* t., *P. diploxylon* t., *Picea*, *Quercus*, *Ericaceae*, *Betula*, and *Ulmus*.

Discussion

Paleoenvironment

The question how the landscape in central Europe might have looked during the last full-glacial period and whether it was virtually devoid of trees has been matter of discussion for a long time. However, in such consideration, it must be taken into account regional differences in vegetation zonation and molluscan assemblages, particularly in a mountainous area like the Western Carpathians range (Ložek, 2000). Both the older data (Środoń, 1966) and more recent data (Willis et al., 2000; Jankovská and Pokorný, 2008) unequivocally stress the refugial role of the Carpathians for many tree taxa like *Pinus sylvestris*, *P. cembra*, *Picea*, *Betula*, and *Salix* during the last full-glacial times. More thermophilous trees like *Carpinus*, *Quercus*, *Ulmus*, *Tilia*, and *Corylus* found their refugial areas farther to the south (Willis et al., 2000).

The few snail species found in last glacial (Vistulian) sediments in the southern Poland have been regarded as indicators of open areas of tundra or steppe-tundra environment. The species that point the presence of at least some pockets of trees are much less numerous. This assumption had to be changed when the set of index glacial species was found living in the Altai mountains (Meng, 2009; Meng and Hoffmann, 2009; Horsák et al., 2010; Hoffmann et al., 2011), hence the reconstruction of Pleistocene environment in central Europe became more reliable. However, reconstruction for the Lower Pleistocene is much more complicated because of the scarcity of paleontological evidence.

The snail assemblage from the bottom part of the core in Jawornik comprises five index glacial species: *Vallonia tenuilabris*, *Columella columella*, *Pupilla loessica*, *Vertigo genesii* and *Vertigo parcedentata* which were recently found inhabiting various types of habitats under conditions of cold macroclimate in the southern part of the Russian Altai (Horsák et al., 2010). Among them only *V. tenuilabris* and *P. loessica* occur as frequently in treeless habitats as in woodlands and scrubs but the former species should not be regarded as typical of glacial steppes because it also occurs in more humid habitats (Meng, 2009). *Vertigo genesii*, both fossil and extant, is reported from very wet habitats, mainly from calcareous fens in treeless areas. Nevertheless, in Finland, the species has been found in wooded fens also, while

https://doi.org/10.1016/j.yqres.2012.02.006 Published online by Cambridge University Press

Table 2
Gastropods from the Jawornik core (broken line indicates the absence of gastropod shells in the sample).

Taxa depth (m)	*Succinea oblonga elongata* Sandberger	*Vallonia tenuilabris* (Sandberger)	*Columella columella* (*G. Martens*)	*Pupilla muscorum* (Linnaeus)	*Pupilla muscorum densegyrata* Ložek	*Pupilla loessica* Ložek	*Pupilla* sp.	*Vertigo genesii* (Gredler)	*Vertigo parcedentata* (Al. Braun)	*Vertigo alpestris* Alder	*Semilimax kotulae* (Westerlund)	Clausilidae	Helicidae
39.00–39.50											+		
39.50–39.80											+		
39.80–40.00											+		
40.00–40.20	------	------	------	------	------	------	------	------	------	------	------	------	------
40.20–40.50											+		
40.50–40.80											+		
40.80–41.00											+		
41.00–41.20											+		
41.20–41.50											+		
41.50–41.80	------	------	------	------	------	------	------	------	------	------	------	------	------
41.80–42.00	------	------	------	------	------	------	------	------	------	------	------	------	------
42.00–42.20	------	------	------	------	------	------	------	------	------	------	------	------	------
42.20–42.50	------	------	------	------	------	------	------	------	------	------	------	------	------
42.50–42.80	------	------	------	------	------	------	------	------	------	------	------	------	------
42.80–43.00	------	------	------	------	------	------	------	------	------	------	------	------	------
43.00–43.20											+		
43.50–43.80											+		
43.80–44.00											+		
44.00–44.20											+		
44.20–44.50											+		
44.50–44.80											+		
44.80–45.00											+		
45.00–45.20											+		
45.20–45.50											+		
45.50–45.80											+		
45.80–46.00											+		
46.00–46.20											+		
46.20–46.50											+		
46.50–46.80											+		
46.80–47.00											+		
47.00–47.50											+		
47.50–47.80											+		
47.80–48.00											+		
48.00–48.35						+					+		
49.00–49.30	+	+						+			+		
49.30–49.50	+	+						+			+	+	
49.50–49.70	+	+				+		+			+	+	
49.70–50.00		+						+			+	+	+
52.00–52.15											+		
52.15–52.40		+			+	+					+		
52.40–52.60										+			
52.50–52.70	+	+		+		+					+		
52.60–52.80		+					+				+		
52.80–53.00	+	+	+			+					+		
53.00–53.20	+	+			+	+			+		+		
53.20–53.35		+				+							
53.35–53.50		+			+						+		
53.50–53.75	+	+			+						+		
53.70	+	+				+							
53.75–54.00	+	+				+					+		
54.00–54.15		+				+					+		
54.00–54.30		+					+						
54.00–54.70	+	+											
54.25–54.75	+	+				+					+		

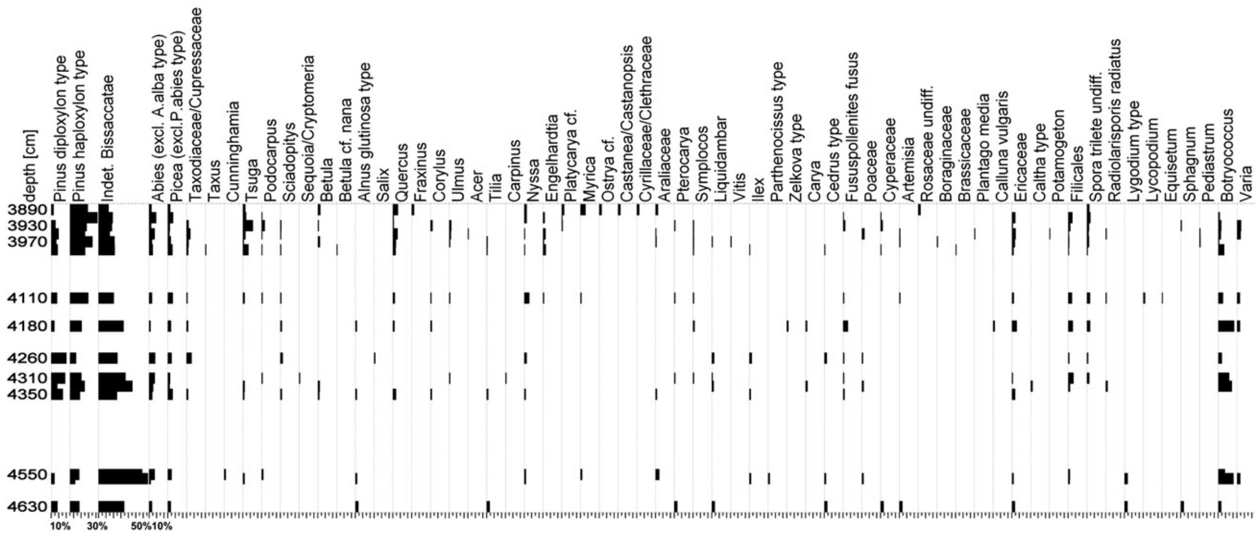


Figure 5. Percentage pollen diagram, Jawornik core.

two samples with *V. genesii* from Karelia came from a humid bank of waterfall with sparse trees (Valovirta, 2003). The remaining two species – *C. columella* and *V. parcedentata* – also prefer wet, base-rich fens although the former species, in Poland found only in the calcareous part of the Tatra Mts., occurs there on epilithic swards. All the above indicates that the environment in which the snail assemblage from Jawornik occurred was perhaps only partly wooded and more-or-less damp. At the end of this period the marked decline of index glacial species began.

In the second phase the climate probably became somewhat milder and warmer such that coniferous woodlands could spread. Under such conditions the montane forest species *S. kotulae* could survive. Therefore, the succession of molluscan assemblages from Jawornik suggests that the phase of partly open and shaded environment with swampy and marshy habitats in a rather cold climate was followed by development of coniferous woodlands when a slight warming of climate took place.

Although the index glacial species could live both in the open and partly wooded areas, they all required low temperatures. Both *V. tenuilabris* and *P. loessica* live in Central Asia in areas with very low average annual temperature, even to −6.7°C (Meng and Hoffmann, 2009). The progressive warming which followed the cold phase may have caused decline of the index glacial species and only *S. kotulae* could persist. *S. kotulae* is generally regarded as a high-montane species that occurs in the Polish mountains usually above 700 m a.s.l. including the subalpine zone. In the Bieszczady Mts. it is at its most abundant at ~1250 m a.s.l. where the average annual temperature is lower than +3°C (Sulikowska-Drozd and Horsák, 2007). Similar inferences come from the investigation in the Bavarian Forest National Park, where its abundance increases with altitude and thus with decreasing temperature (Müller et al., 2009). During the cold phases of the Pleistocene *S. kotulae* was spread beyond its present distribution range, and at lower altitudes. In the late Vistulian and in the early Holocene it existed both with snails typical of the taiga-type biotope and with cold-tolerant tundra forms. Unfortunately, the pollen record from the portion of the sediments bearing the cold-loving mollusc assemblage is nearly pollen-free (Fig. 3). The very poor state of preservation of the sporomorphs from the Jawornik core and their extremely low concentration in the sediments may suggest their redeposition from the older sediments. It may also point to a very sparse contemporaneous vegetation, the development of which was not recorded by pollen rain. On the other hand, in the second phase the pollen flora points to development of pine boreal forest communities under conditions of clearly milder climate (Fig. 5). It is in accordance with the modern occurrence of *S. kotulae*, which is confined to wooded areas mainly in the mountains and humid, rather cold microhabitats.

Table 3
Pollen spectra from the lower part of the Jawornik core.

Depth, m	Pollen spectrum*
49.90	Indet. Bissaccatae +, *Ulmus*, *Pinus haploxylon* t., cf. *Engelhardtia*, *Botryococcus*
50.00	Indet. Bissacctae +, *Pinus haploxylon* t., Cyrillacae/Clethraceae, *Lygodium*
51.20	No pollen
53.40	No pollen

* Sporomorphs with more than four finds are marked with "+"; unmarked sporomorphs are single finds.

Age

When considering the age of silt deposits with organic remains it is important to remember that the snail shells and pollen flora in the Jawornik core are located below the till. This means that these deposits predate the glacial sediments of the Narevian glaciation = Manepian and were therefore deposited during the Eopleistocene or Lower Pleistocene. The results of malacological and palynological analyses do not provide a definite answer as to the stratigraphic position of these deposits. Malacological analysis shows that the lower part of the sediment was deposited under cold climate conditions. The presence of typical "cold" forms may slightly suggest a correlation of the lower part of our series with the strong cool signal recorded in sediments of Krems in Austria (Kohl, 1986), which was associated with the Jarmillo event in paleomagnetic record (1.06–0.9 Ma).

In Poland, several localities with faunal (mainly small and large mammals) remains of early Pleistocene age have been described (Nadachowski, 1990, 1998). Among them the most interesting for us is that in Żabia Cave, correlated with the Lower Biharian (1.5–1.7 Ma) which offers some evidences of migration of Asiatic species associated with cool climate into central Europe in the early Pleistocene (Nadachowski et al., 2011). Only two rich in gastropods remnants localities are known from Poland (Stworzewicz, 1981; Skompski, 1996). Unfortunately they both represent mostly warm-loving malacofauna with species characteristic for interglacial forest communities.

Based on rodents, particularly *Dicrostonyxini* remains, at least three cold phases can be recognized in the Lower Pleistocene

(Nadachowski, 1990). Regarding the climate demands of the determined snail species and the position of the sediments beneath the glacial till of the maximal Scandinavian ice sheet one may suppose the age of the studied mollusc assemblages is older than the Narevian (= Manepian).

Summary

The Pleistocene sediments bearing fauna and flora remains were recognized in the core from Jawornik (the Carpathian Foothills). These sediments underlay the till deposits which could have been deposited during the maximal advance of the Scandinavian ice sheet reaching the Carpathians Mts. Paleomagnetic data from sediments at the Carpathians border strongly suggest, that it was the Narevian (= Manepian) glaciation (~1.2 Ma) — the oldest one from the South Polish Complex. This is the first finding of organic sediments of the early Pleistocene age in the Carpathians situated beneath the glacial till.

Thirteen land snail taxa were identified in 55 core samples which formed two molluscan assemblages (Table 2). The bottom part contained mainly typical cold-loving snails regarded as index glacial species: *Vallonia tenuilabris*, *Columella columella*, *Pupilla loessica*, *Vertigo genesii* and *Vertigo parcedentata* whereas in the upper part only *Semilimax kotulae* was present. Due to low sporomorph concentration pollen analysis of the sediments was performed only for the upper part of the profile. The results of pollen analysis suggest temperate climate conditions during the upper part of the sediments. This conclusion is also supported by the lack of index glacial snail species.

In general, the organic remains point to a cold climatic phase at lower part of the profile with progressive warming.

Acknowledgments

We thank R.A.D. Cameron for helpful comments on this manuscript and linguistic revision of an earlier version, and anonymous reviewer for his insightful suggestions. Special thanks are due to Professor Alan Gillespie for constructive criticism greatly improving the paper.

References

Ber, A., 2005. Polish Pleistocene stratigraphy — a review of interglacial stratotypes. Netherlands Journal of Geosciences – Geologie en Mijnbouw 84, 61–76.
Ber, A., Lindner, L., Marks, L., 2007. Propozycja podziału stratygraficznego czwartorzędu Polskiego. Przegląd Geologiczny 55, 115–118.
Butrym, J., Gerlach, T., 1985. Przyczynek do chronostratygrafii osadów zlodowacenia południowopolskiego na Pogórzu Dynowskim. Studia Geomorphologica Carpatho-Balcanica 19, 29–35.
Foltyn, E., Foltyn, E.M., Jochemczyk, L., Nawrocki, J., Nita, M., Waga, J.M., Wójcik, A., 2010. The oldest human traces north of the Carpathians (Kończyce Wielkie 4, Poland). Journal of Archaeological Science 37, 1886–1897.
Frank, C., 2006. Plio-pleistozäne und holozäne Mollusken Österreichs. Verlag der Österreichischen Akademie der Wissenschaften, Wien.
Fűköh, L., Krolopp, E., Sümegi, P., 1995. Quaternary Malacostratigraphy in Hungary. Malacological Newsletter Supplement 1, 1–219.
Hoffmann, M., Meng, S., Kosachev, P.A., Terechina, T.A., Silanteva, M.M., 2011. Land snail faunas along an environmental gradient in the Altai Mountains (Russia). Journal of Molluscan Studies 77, 76–86.
Horsák, M., Chytrý, M., Pokryszko, B.M., Danihelka, J., Ermakov, N., Hájek, M., Hájková, P., Kintrová, K., Koči, M., Kubešova, S., Lustyk, P., Otýpková, Z., Pelánkova, B., Valachovič, M., 2010. Habitats of relict terrestrial snails in southern Siberia: lessons for the reconstruction of palaeoenvironments of full-glacial Europe. Journal of Biogeography 37, 1450–1462.
Jankovská, V., Pokorný, P., 2008. Forest vegetation of the last full-glacial period in the Western Carpathians (Slovakia and Czech Republic). Preslia 80, 307–324.
Krolopp, E., Sümegi, P., 1993. Pleistocene *Vertigo* species from Hungary. Scripta Geologica, Special Issue 2, 263–268.
Kohl, H., 1986. Pleistocene glaciations in Austria. Quaternary Science Reviews 5, 421–427.
Lindner, L., 1992. Stratygrafia (klimatostratygrafia) czwartorzędu. In: Lindner, L. (Ed.), Czwartorzęd, osady, metody, stratygrafia. PAE, Warszawa, pp. 441–633.
Lindner, L., Marks, L., 2008. Pleistocene stratigraphy of Poland and its correlation with stratotype sections in the Volhynian Upland (Ukraine). Geochronometria 31, 31–37.
Ložek, V., 1964. Quartärmollusken der Tschechoslowakei. Rozpravy Ústředniho ústavu geologického 31, 1–374.
Ložek, V., 2000. Palaeoecology of Quaternary Mollusca. Antropozoikum 24, 35–59.
Malata, T., 2009. Szczegółowa mapa geologiczna Polski w skali 1:50,000, arkusz Strzyżów. Centralne Archiwum Geologiczne, Warszawa.
Mamakowa, K., 2003. Plejstocen. In: Dybova-Jachowicz, S., Sadowska, A. (Eds.), Palinologia. Wydawnictwa Instytutu Botaniki PAN, Kraków, pp. 235–266.
Mania, D., 1973. Paläoökologie, Faunenentwicklung und Stratigraphie des Eiszeitalters im mittleren Elbe–Saalegebiet auf Grund von Molluskengesellschaften. Geologie 21, 1–175.
Meng, S., 2009. Rezente zentralasiatische und pleistozäne mitteleuropäische Faunen mit *Vallonia tenuilabris* (A. Braun, 1843). Mollusca 27, 61–82.
Meng, S., Hoffmann, M.H., 2009. *Pupilla loessica* Ložek 1954 (Gastropoda: Pulmonata: Pupillidae) — "A Living Fossil" in Central Asia? Eiszeitalter und Gegenwart. Quaternary Science Journal 58, 55–69.
Mojski, J.E., 1985. Geology of Poland. Stratigraphy, Cainozoic, Quaternary. I, 3b, Geological Institute. Wydawnictwa Geologiczne, Warszawa, pp. 7–185.
Müller, J., Bässler, C., Strätz, C., Klöcking, B., Brandl, R., 2009. Molluscs and climate warming in a low mountain range National Park. Malacologia 51, 89–109.
Nadachowski, A., 1990. Lower Pleistocene rodents of Poland: faunal succession and biostratigraphy. Quartärpaläontologie 8, 215–223.
Nadachowski, A., 1998. Faunal succession of small mammal assemblages at the Pliocene–Pleistocene boundary in Poland. Mededelingen Nederlands Instituut voor Toegepaste Geowetenschappen TNO 60, 281–286.
Nadachowski, A., Stefaniak, K., Szynkiewicz, A., Marciszak, A., Socha, P., Schick, P., August, C., 2011. Biostratigraphic importance of the Early Pleistocene fauna from Żabia Cave (Poland) in Central Europe). Quaternary International 243, 204–218.
Poliński, W., 1927. Ślimaki z dyluwjum Kielc (Gastéropodes diluviaux de Kielce). Posiedzenia Naukowe Państwowego Instytut Geologicznego 17, 21–22.
Skompski, S., 1996. Standard assemblages of malacofauna in different Quaternary stratigraphic units (in Polish, English summary). Prace Państwowego Instytutu Geologicznego 151, 1–47.
Stuchlik, L., 1994. Some Late Pliocene and Early Pleistocene pollen profiles from Poland. Cenozoic plants and climates of the Arctic: In: Boulter, M.C., Fisher, H.C. (Eds.), NATO ASI, Series, 1(27).
Stworzewicz, E., 1981. Early Pleistocene Land Snails from Kielniki and Kozi Grzbiet (Poland). Folia Quaternaria 54, 43–77.
Sulikowska-Drozd, A., Horsák, M., 2007. Woodland mollusc communities along environmental gradients in the East Carpathians. Biologia, Bratislava 62, 201–209.
Szafer, W., 1954. Pliocene flora from the vicinity of Czorsztyn (West Carpathians) and its relationship to the Pleistocene. Prace Instytutu Geologicznego 11, 1–238.
Środoń, A., 1966. Outline of the historical development of the vegetation of Poland in the Late-glacial and Post-glacial Periods. In: Szafer, W. (Ed.), The Vegetation of Poland. PWN, Oxford, New York, Pergamon, Warszawa, pp. 561–593.
Valovirta, I., 2003. The habitat and status of *Vertigo angustior*, *V. genesii* and *V. geyeri* in Finland and nearby Russian Karelia. Heldia 5, 85–94.
Willis, K.J., Rudner, E., Sümegi, P., 2000. The full-glacial forests of central and southeastern Europe. Quaternary Research 53, 203–213.
Wójcik, A., 1999. Tektoniczne deformacje utworów glacjalnych i limnoglacjalnych w Niebylcu (Karpaty, Pogórze Strzyżowskie). VI Konferencja stratygrafii plejstocenu Polski "Czwartorzęd wschodniej części Kotliny Sandomierskiej", pp. 93–96.
Wójcik, A., 2003. Czwartorzęd zachodniej części Dołów Jasielsko-Sanockich (polskie Karpaty Zewnętrzne). Prace Państwowego Instytutu Geologicznego 178, 1–148.
Wójcik, A., Nawrocki, J., Nita, M., 2004. Pleistocene in the Kończyce profile (Oświęcim Basin)—sediment genesis and age analysis at the background of stratigraphic schemes of the Quaternary. Summary. Biuletyn Państwowego Instytutu Geologicznego 409, 47–50.
Zagwijn, W.H., 1985. An outline of the Quaternary stratigraphy of the Netherlands. Geologie en Mijnboun 64, 17–24.