GEOCHRONOMETRIA 50 (2023): 224–249
DOI 10.2478/geochr-2023-0018

Available online at
https://content.sciendo.com/view/journals/geochr/geochr-overview.xml

CONFERENCE PROCEEDINGS OF THE 14TH INTERNATIONAL CONFERENCE "METHODS OF ABSOLUTE CHRONOLOGY" May 17-19TH, 2023, GLIWICE, POLAND

IMPACTS OF LARGE-SCALE CLIMATE OSCILLATIONS ON FLUVIAL SEDIMENTS IN CENTRAL POLAND: EVIDENCE FROM GEOCHRONOLOGICAL ANALYSIS

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Received 29 June 2023 Accepted 25 January 2024

Abstract
The article presents the results of a collective analysis of 181 radiocarbon and 38 luminescence dating results from the time range 50-11.7 cal kBP for samples originating in fluvial sedimentary environment in Łódź region (central Poland), south of the last glacial maximum (LGM) line. Four sites were selected for a general of fluvial deposits and the obtained dating results Struga Żłobnicka, Parchliny, Warenka, and Swędów regions. Based on the summed probability density function (PDF) curves, the study demonstrates the response of the fluvial sedimentary environment to events of overregional scale. The collective analysis of the radiocarbon age determinations from the Łódź region allows for observing the correlation between local environmental changes and large-scale changes recorded in the NGRIP core. The warming periods Greenland interstadials (GI)-3, GI-4, and GI-5.1, the cooling event GI-1b within the warming GI-1, as well as the transition between GI-1a and Greenland stadials (GS)-1, were most prominently recorded in the PDF curves. The collective analysis of the luminescence age determinations reflects a change in the river valleys, expressed by a strong aggradation during the cold maximum of the studied period.

Keywords
fluvial sedimentary environment, radiocarbon dates, luminescence dates, probability density function, 50-11.7 cal kBP, Łódź region

1. Introduction

Climatic fluctuations are recorded in the sequential formation of various sediments. In old-glacial zones, these are especially fluvial records which reflect changing dynamics of geomorphological processes. In numerous studies focusing on reconstruction of the history of sedimentary environments induced by large-scale climate changes, age determinations are made using the basic geochronometric methods: radiocarbon and luminescence. The latest increase in this type of data creates an opportunity to undertake statistical studies aimed at analysing whether it is possible to conclude on environmental changes in measurable time units about the area from which the data was collected. The results obtained in earlier studies confirm the validity of this type of approach for the fluvial environment

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ISSN 1897-1695 (online), 1733-8387 (print)

(e.g. Michczyńska and Pazdur, 2004; Michczyńska *et al*., 2007; Gębica *et al*., 2015; Dzieduszyńska, 2019; Michczyńska *et al*., 2022). This type of research is facilitated by the fact that in most cases samples were taken from places where a significant change in the sedimentological record occurred. These are, for example, facies changes, the bottom and top of organic inserts or significant changes in pollen diagrams. It is assumed that these changes, in many cases, must have been a response to global climatic impulses, which, combined with a thorough understanding of the geological and geomorphological characteristics of the selected sites and the regional palaeogeographic development (e.g. Turkowska, 2006), can be applied in statistical analyses. The data we have suggest long-term periods with unchanging trends, reaching even several thousand years, which, given the current state of knowledge about the dynamics of environmental changes, seems unlikely (e.g. Huntley *et al*., 2003; Dzierżek and Szymanek, 2013; Helmens, 2014; Gębica *et al*., 2015; Marks *et al*., 2016). Vistulian evolution of an extraglacial fluvial environment in NW Europe also does not provide information concerning river reaction on small-scale climatic changes identified in the Greenland ice-core record (e.g. Vandenberghe, 1985; Van Huissteden, 1990; Mol, 1997; Vandenberghe, 2002; Kasse *et al*., 2003).

The aim of the article is to check, using the example of data from river valleys in the Łódź region (Central Poland), whether the shape of the probability density function curves (PDF) obtained on the basis of a set of radiocarbon and luminescence dates can reflect the development trends of river valleys. Based on combined geochronological data, the authors look for signals of climatic fluctuations which so far were problematic in identification in the fluvial environment. The analysis concerns the time section of the Vistulian between 50 cal kBP and 11.7 cal kBP, when serious climatic fluctuations occurred. Comparison with the Greenland ice-core record (Rasmussen *et al*., 2014), which is a palaeoclimatic model for the North Atlantic region, allows to see in the seemingly local impulse the reaction to global events.

2. Study Area: Location and Palaeogeographical Background

Sampling sites included in the database of the present study are located in the old-glacial zone of Central Poland, in the area named Łódź region (**Fig. 1**). It is lowland area with a little diversified relief, with a meridional zone of the highest altitudes exceeding 200 m above sea level. This area, covered mostly with glacial and glaciofluvial sediments, has been dissected by valleys of numerous, though mainly small rivers, which belong to the Vistula River or Odra River catchments. The possibility of a broad insight into the geological structure of all stages of the Quaternary in the Łódź region was provided from extensive excavations available in the brown-coal open-cast mines at Bełchatów and Adamów.

The palaeogeographical evolution of the Łódź region generally followed the rhythm of global environmental changes. The most important stage in the formation of river valleys falls on the last glacial stage. The history of river valleys registered the main events included in the chronostratigraphic scheme covering the Early Vistulian, Plenivistulian and Late Vistulian. Middle and Upper Plenivistulian and Late Vistulian periods are considered in the article. The chronostratigraphic scheme applied is originally derived from the vegetation change cycle for NW Europe introduced by van der Hammen *et al*. (1967) and then successively regionally developed by various researchers (the latest approach by Marks *et al*. (2016). The Middle Plenivistulian (approx. 58–29 cal kBP; see Lisiecki and Raymo, 2005) was characterised by relatively well-defined warm and cold phases and the Upper Plenivistulian (29–15 cal kBP) by a cold maximum during the last glacial maximum (LGM). In the Late Vistulian (15–11.7 cal kBP) a non-linear warming trend occurred.

In the Middle Plenivistulian, river erosion initially dominated in the valleys of the Łódź region, to give way to accumulation over time. Sedimentary succession begins with fine-grained sand with thick silt and/or sand with interbedding of organic sediments. The Upper Plenivistulian cooling brought about a fundamental change in the sedimentation style expressed by the deposition of sandy sediments in the high-energy environment of a braided river system. Such succession is revealed in the geological structure of high terrace levels, which emerged morphologically due to the result of erosion at the end of the Upper Plenivistulian. The subsequent relative stabilisation in the functioning of river valleys frequently led to a shift in the channel pattern into meandering with large meanders. Palaeochannels were cut off and filled with biogenic deposits, as well as formation of valley peatbogs or extensive basins on floodplains were established. At the end of the Late Vistulian, there was an intensification of fluvial processes, expressed by increased floods and covering of floodplains with mineral deposits which form the surfaces of low terraces morphologically emerged in a later period (see Dzieduszyńska *et al*., 2020).

3. Material and Methods

The results of radiocarbon and luminescence age determinations of fluvial sedimentary environment formed between 50 cal kBP and 11.7 cal kBP were

Fig 1. Study area. ***(A)*** *– against the selected ice-sheet limits (after Marks et al., 2018; Palacios et al., 2023).* ***(B)*** *– distribution of sites included in the dataset in the Łódź region.*

collected (see Supplementary). Examples of four sites (Struga Żłobnicka, Parchliny, Warenka and Swędów) where detailed sedimentological studies were carried out are provided (**Fig. 1**). However, in no case a complete profile from this period has been found. Although the timespan of interest of the present article covers the interval 50–11.7 cal kBP, thus from the calibration curve extent to the Holocene beginning, dates from the beginning of the Holocene were also added to the set of ages to obtain a methodically correct image of the end of Vistulian. The dating results included in the database come from: (1) numerous publications by various researchers, (2) research by the authors of this publication and (3) unpublished results provided as a courtesy. The reliability of the dates included in the database is confirmed by geological, geomorphological, palynological or paleozoological data, keeping in mind all limitations which result from complexity of environment and principles of the used methods of dating. The authors of the works from whom we have taken the data (see Supplementary) had no doubts about the stratigraphic position of the examined sediment and the dating results. This database also includes dates that come from the latest, not yet published research by the authors of this article, but also with stratigraphic position that does not raise any doubts. Currently, it is a complete set for the analysed area, containing 181 results of age determinations using the radiocarbon method and 38 results of age determinations using the luminescence method.

The present study used these age determinations which have been positively verified in terms of the certainty of assigning them to the tested fluvial environment. Dates assigned to the fluvial environment carry information about the processes taking place there. This means that lithology was not always a key determinant. The results of radiocarbon dating of sediments of the overbank facies such as palaeochannels' infillings, sediments of decantation basins, hydrogenic soils, sediments of valley peatlands and lumps of organic or organic-mineral material deposited in mineral alluvium were considered, provided that their formation was found to be in a direct connection with fluvial environment. The results of luminescence dating come primarily from mineral deposits of the overbank facies.

Statistical studies consisted in the construction of curves of the PDF. PDF curves were created using OxCal programme (Bronk Ramsey, 2009, 2017). For radiocarbon dates, the latest IntCal20 calibration curve (Reimer *et al.*, 2020) was used. The PDF curves show grouping of dates in several time ranges, corresponding to overregional trends of environmental changes. It was assumed that changes in the environment will be expressed in PDF peaks. A local signal specific to only one site is smoothed, while a regional or global signal is amplified. The main step is to see if the summed frequency distributions of dates can be used to demonstrate the response of fluvial sedimentary environment to large-scale events and to investigate whether this response was synchronous. The resulting curves were compared with the oxygen curve from the NGRIP core and INTIMATE stratigraphy (Rasmussen *et al.*, 2014).

The accuracy of the reconstruction depends on the precision of the dates used for the analyses. The highest resolution can be obtained using radiocarbon dates obtained with the AMS technique. However, for the study area, such age determinations represent a small percentage of the collected database. Another group consists of ^{14}C dating results obtained using conventional techniques (GPC or LSC). Although they have higher uncertainties compared to AMS dates, they originate from well-recognised palaeogeographical background and date events recorded in the fluvial environment of the Łódź region. It can be expected that, in their collective analysis, the peaks of the probability density distributions will have a greater width, but there is no basis to question their usefulness in the conducted analysis. It should be noted here that, based on the statistical foundations of the dating method, the uncertainties of dates increase with the age of the sample. Therefore, with age, the peaks of the PDF curves will become lower and wider.

Despite high uncertainties of luminescence dates, the authors decided to include them in the database as well, because they are a valuable supplement to the picture obtained on the basis of organic material. Luminescence dates, like radiocarbon dates, come from the last several decades of research in the region. Most of them were made using the optically stimulated luminescence (OSL) technique at the Gliwice Luminescence Laboratory. Increased activity of the fluvial environment associated with the aggradation of mineral alluvium happened in cold periods, hence the correlation with the Greenland stadials (GS) is expected. In turn, stabilisation of river beds and sedimentation of organic material is generally favoured by warmer conditions. Thus, radiocarbon dates are expected to be primarily correlated with Greenland interstadials (GI). However, since the study area belongs to an extra-glacial zone, it is not surprising that some of the dated organic material may be related to GS.

4. Results

4.1. Alluvial Depositional Succession in the Selected Profiles

Sites Struga Żłobnicka and Parchliny are located in the Widawka catchment, right tributary of the Warta River (**Fig. 1B**). The area is situated within the active subsidence zone of the Kleszczów Graben, thus the depositional succession is well preserved. Geological data were gathered from the walls exposed along Bełchatów excavation

(Struga Żłobnicka) and Szczerców excavation (Parchliny) of the Bełchatów Lignite Open Cast Mine. Vistulian deposits are represented by the local, the Piaski Formation, which a few sedimentary members (e-a) consisting mainly of sands and silts (Baraniecka, 1980; Hałuszczak, 1982; Krzyszkowski, 1990, 1991, 1992; Goździk and Zieliński, 1996; Manikowska, 1996; Kasse *et al*., 1998; Krzyszkowski, 1998).

In ***Struga Żłobnicka*** locality (**Figs. 1B and 2**) fluvial deposits of the Piaski Formation are underlain by lacustrine deposits (member **e**). River alluvium (member **d**) starts with erosional pavement and forms thick horizon of silty-sandy deposits with organic interlayers which originated in meandering river system. Alternation of sand and silt lithofacies associations is a characteristic feature. The lithofacies associations of different thickness reveal erosional contact. Channel facies is dominated by sand while overbank facies consists of sandy-silt and silt. The bottom part of the member was radiocarbon dated at 23.6 ± 0.4 kBP (Gd-5484; 68.3% prob. 28.18–27.35 cal kBP). The dated material is organic layer probably from decantation basin. Transition between members **d** and **c** is of depositional nature, indicating the tendency to aggradation, likely in multichannel river environment. Member **c** consists of sand and silty-sand. Termination of this member sedimentation occurred at 21.97 ± 0.81 kBP (Gd-777; 68.3% prob. 27.23–25.60 cal kBP) as indicated from radiocarbon dated peat sample. Member **b** includes sand deposited primarily in high-energy environment of braided river, and then in a less dynamic regime. The bottom part of this member was radiocarbon dated at 20.17 ± 0.25 kBP (Lod-737; 68.3% prob. 24.54–23.90 cal kBP) while the top part of the member was dated at 12.44 ± 0.18 kBP (Gd-2640; 95.4% prob. 14.96–14.26 cal kBP); both dates are ascribed to silty organic layers. The whole profile of alluvia is topped with sand of member a, representing fluvioaeolian sediments typical of the Late Vistulian, in which there are also peat interbeddings radiocarbon dated to 10.16 ± 0.14 kBP (Gd-2189; 68.3% prob. 12.04–11.40 cal kBP) and 11.17 ± 0.11 kBP (Gd-1707; 68.3% prob. 13.17–12.93 cal kBP).

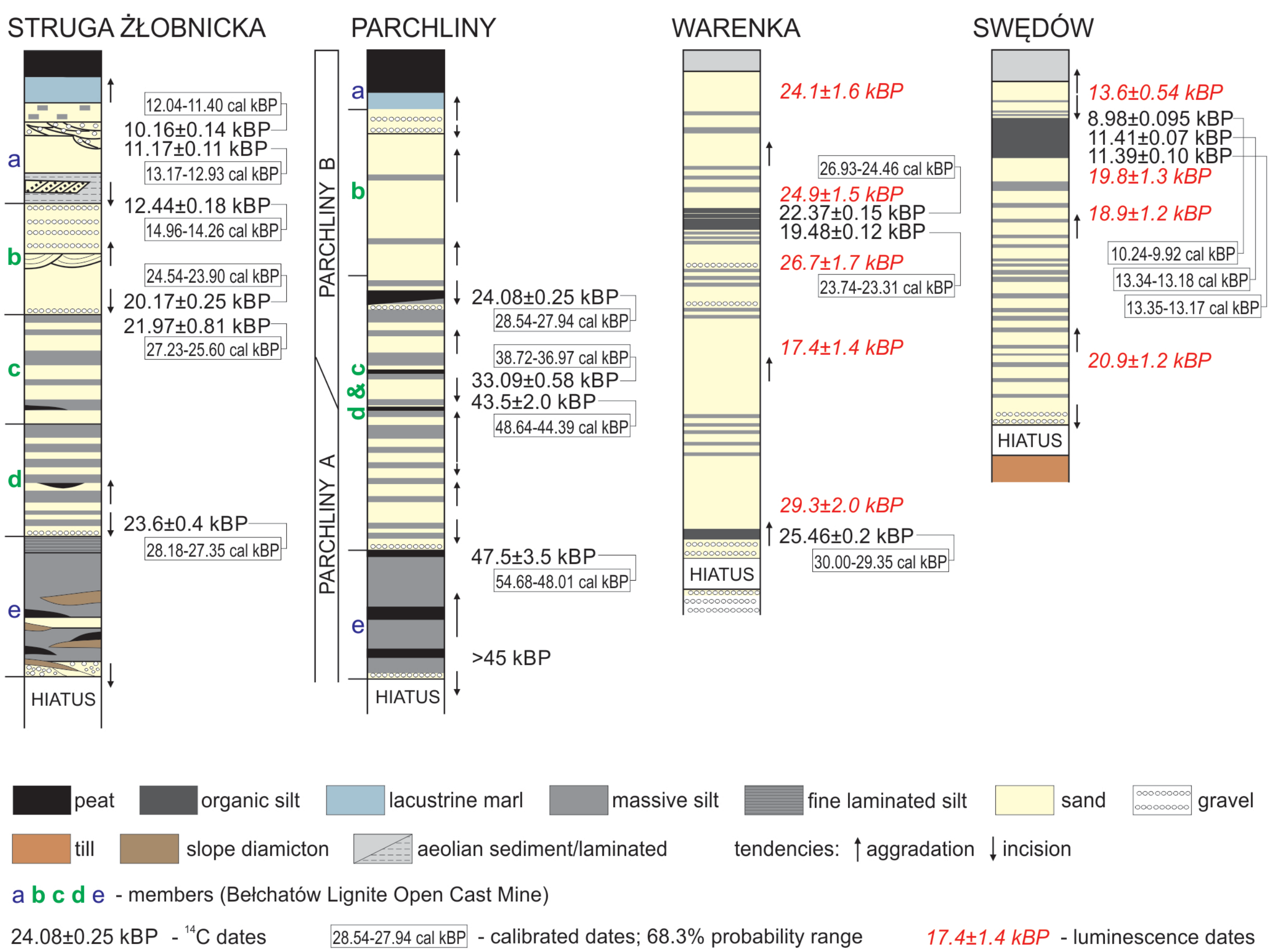

Fig 2*. Synthetic lithological profiles.*

In ***Parchliny*** locality (**Fig. 1B**), fluvial deposits (**d**–**b** members) are of the thickness of several metres. They lie above the erosional surface separating the Vistulian deposits from the older ones (Wachecka-Kotkowska *et al*., 2018). Sand and silty-sand series of the Piaski Formation fill the pra-Krasówka valley which used subglacial channel there (Wieczorek and Stoiński, 2019) and melt-out depressions (Majecka *et al*., 2022).

The oldest deposits were recognised in ***Parchliny A*** profile (**Fig. 2**), at a depth of *ca*. 14.9 m, where among silts and sandy silts with an organic admixture (**e** member), formed on the floodplain or in a water reservoir, and these organic deposits were radiocarbon dated in the bottom at >45 kBP (GdC-476; >47 cal kBP). In the top of organic silt series, at a depth of 14.2 m, a radiocarbon date of 47.5 ± 3.5 kBP (GdS-1127; 68.3% prob. 54.7–48 cal kBP) was obtained. Mineral-organic deposits overlie gravelly boulder pavement, indicating a strong erosion phase before their deposition. Above the gravels, there is a sandy-silty and silty-sandy series (member **d**) of *ca*. 8.5 m thick, which on the basis of lithofacies, can be interpreted as formed in the channel zone, at low water levels, and in the overbank zone (Wachecka-Kotkowska *et al*., 2014). In the upper part of the Piaski Formation at a depth of 5 m below the present-day surface, organic material within very-fine grained sand series was radiocarbon dated to 43.5 ± 2.0 kBP (GdS-1128; 68.3% prob. 48.65–44.35 cal kBP).

In the nearby ***Parchliny B*** profile (**Fig. 2**), above the erosional surface, in sandy-silt sediments with organic admixtures (c member), within the bottom of sandy-muddy sediments, at a depth of 13.6 m a radiocarbon date of 33.09 ± 0.58 kBP (GdS-1366; 68.3% prob. 38.75–36.95 cal kBP) was obtained. About 1.3 m higher (12.3 m deep), at the top of sandy silt deposits, organic remains found in situ were radiocarbon dated at 24.08 ± 0.25 kBP (GdS-1371; 68.3% prob. 28.55–27.9 cal kBP). Though the Intensity of erosion decreased, the erosional base was relatively stable.

Ca. 28–27 kBP an increased aggradation of sand and subordinately of silt with sand (member **b**) occurred in the pra-Krasówka valley. A thicker series even over 12 m was formed, with aeolian processes from the end of the Vistulian involved (Wachecka-Kotkowska *et al*., 2014). At the end of the Plenivistulian, as a result of aeolian (deflation) and fluvial processes (member **a**), a depression in the top of sandy series discussed above was formed and filled with peat (Forysiak, 2012).

Site ***Warenka*** (**Fig. 1B**) is located in the Warta River valley, in the section of the tectonic Adamów Graben. Tectonic conditions favoured sedimentation and preservation of thick series of deposits, including the Vistulian ones. Sedimentary studies were carried out in excavations of Adamów Lignite Open Cast Mine. Vistulian fluvial deposits, usually to 20 m thick, rest on glacial till or glaciofluvial sand and gravel. They form there Plenivistulian high terrace of the Warta River. Alluvia are dominated by sand of various fraction; the presence of mineral-organic interlayers in superposition (**Fig. 2**) is their characteristic feature. The top of the lower mineral-organic interlayer was radiocarbon dated at 25.46 ± 0.20 kBP (GdA-6447; 68.3% prob. 30.00–29.35 cal kBP). Then there is a series of sand of about 10 m, mainly medium-grained, which were dated by OSL technique. The following results were obtained: 29.3 ± 2.0 kBP (GdTL-3532), 17.4 ± 1.4 kBP (GdTL-3440) – however this result differs from the others and is too young – and 26.7 ± 1.7 kBP (GdTL-3531). Above, there is a change in depositional style – sandy silt interbeds and organic mud appear. Radiocarbon dating of organic mud gave results: 19.48 ± 0.12 kBP (GdA-6446; 68.3% prob. 23.73–23.31 cal kBP) and 22.37 ± 0.15 kBP (GdA-6445; 68.3% prob. 26.93–26.46 cal kBP). The last member of the studied succession is medium-grained sand OSL dated at 24.9 ± 1.5 kBP (GdTL-3530) and 24.1 ± 1.6 kBP (GdTL-3529). Thick sandy series registered in the Warenka profile were deposited in a system of a shallow sand-bed braided river.

Site ***Swędów*** is located in the Moszczenica River valley (**Figs. 1B and 2**). It is a small river, which in some sections has developed a valley clearly cut into the plateau, with well-defined morphological elements. The slope of the valley is gentle but clearly pronounced. The higher terrace of Plenivistulian age is elevated above the valley floor for *ca*. 5 m and is undercut by the currently functioning riverbed and in places forms steep walls. The lower terrace of Late Vistulian age is slightly *ca*. 1 m elevated above the narrow valley floor. Vistulian alluvium is underlain by glacial till, which is covered with a gravel-sandy layer of erosional pavement. Above, there is a series of sand of several metres, mainly medium-grained, with silt interbedding, with more mud interbedding in the lower part of the profile. Sandy-silty series was deposited in the overbark facies. Three age determinations were obtained using OSL method from the described series: 20.9 ± 1.2 kBP (GdTL-3141), 19.8 ± 1.3 kBP (GdTL-3137) and 18.9 ± 1.2 kBP (GdTL-3140) (**Fig. 2**). In the next stage of the valley development, deep erosion occurred, which led to the morphological separation of a high terrace. Sedimentary record finishes with Late Vistulian record and is represented by silt, fine-grained sand and then mineral-organic mud, which also developed in the overbank facies in the distal part of the floodplain. Mineral-organic series was radiocarbon dated at: 11.39 ± 0.10 kBP (GdS-3963; 68.3% prob. 13.35–13.16 cal kBP), 11.410 ± 0.065 kBP (GdS-3970; 68.3% prob. 13.34–13.18 cal kBP) and 8.980 ± 0.095 kBP (GdS-3983; 68.3% prob. 10.24–9.91 cal kBP); the last of the results was too young, verified by pollen analysis (Petera-Zganiacz *et al*., 2019). The top of these sediments has been washed-out. The sequence of fluvial sediments ends with a series of sands with silt interbedding OSL dated at 13.60 ± 0.54 kBP (GdTL-3142).

4.2. Results of the Analysis of Luminescence and Radiocarbon Dates Distributions

The probability distributions of luminescence and radiocarbon dates against the oxygen curve from the NGRIP core and the INTIMATE stratigraphy (Rasmussen *et al*., 2014) are presented in **Figs. 3 and 4,** respectively. It was decided to present the results in two separate time intervals due to the dominant share of radiocarbon dates >15.0 cal kBP: in the range <15.0 cal kBP and >15.0 cal kBP. In order to be able to compare the distribution of luminescence and radiocarbon dates, a common time scale described as 'cal BP' was used, which in the case of luminescence dates should be understood as calendar years before AD (Anno Domini) 1950, and in the case of radiocarbon dates as calibrated years before AD 1950. In each of the figures (**Figs. 3A,B and 4A,B**) the dates were presented as a 68.3% probability range (horizontal bars with the medians (dots) for luminescence dates). In addition, **Figs. 3C, 4c.1 and 4c.2** show the results of the calibration of subgroups of ^{14}C dates, which are well correlated with periods of interstadials or boundaries resulting from the INTIMATE stratigraphy (marked in **Figs. 3D and 4D**).

4.2.1. Probability distributions of luminescence dates

Although the collected set of luminescence dates is not very extensive (comprising only 38 dates), a dominant characteristic emerges, i.e. the majority of luminescence dates is in the time range of 27–15 cal kBP. The overall probability distribution of luminescence dates encompasses five peaks. The peak at approx. 37 cal kBP is derived from a single date. The next peak with a maximum around 32–30 cal kBP is based on three dates and corresponds to GS-5.2–GS-5.1 (see **Fig. 3D**). Two distinct clusters of luminescence dates are evident in GS-3 and GS-2b, comprising 14 and 7 dates, respectively. The youngest peak at around 13.5 cal kBP is formed by 10 dates (see **Fig. 4A**). These dates exhibit large uncertainties and, therefore, collectively form a single peak. However, their stratigraphic position in the deposits indicates that they should be associated with specific cooling periods within GI-1 and GS-1.

4.2.2. Probability distributions of radiocarbon dates

The analysis of the shape of the PDF curve for radiocarbon dates allows us to make the following observations:

- The oldest ^{14}C dates come from the Parchliny site (GdS-1127; 47.5±3.5 kBP and GdS-1128; 43.5±2.0 kBP). Despite the large uncertainties and overlapping calibrated date distributions, additional information from the exposure suggests that the dated material spans 10 m of sediment, allowing these dates to be attributed to GI-13 and GI-12, respectively.
- Another date, 36.31 ± 1.86 kBP (Lod-881) from the Warta River valley in Koźmin site located near Warenka site, has a wide probability distribution after calibration. Although the peak aligns with GI-10 (see **Fig. 3C**), it is uncertain which of the GI-11–GI-9 interstadials it should be associated with.
- Interstadial GI-8 is represented by four dates, each from a different site. A distinct peak at the end of GI-8 comes from one of these dates with the smallest uncertainty.
- Four dates can also be associated with interstadial GI-7, but the uncertainties are large, causing the calibrated probability distribution peak derived from these dates to be blurred and weakly represented in the overall distribution (**Figs. 3B and 3C**).
- Interstadials GI-6 and GI-5.2 are poorly defined on the PDF curve. Four dates can be correlated with them, but their uncertainties are significant, making detailed interpretation more challenging.
- The next three peaks in the distribution, correlated with GI 5.1 (8 dates), GI-4 (7 dates) and GI-3 (7 dates), are clearly pronounced.
- There are no dates from the short interstadials GI 2.2 and 2.1. However, a peak formed by three dates appears just before GI 2.2, and a peak from one date occurs at the GI 2.1/GS-2c transition.
- The boundaries of GS-2c/2b and GS-2b/2a are represented by peaks derived from one and three dates, respectively.
- The increasing number of age determinations begins around 17 cal kBP.
- The GS-2a/GI-1e transition is represented by five dates with relatively large uncertainties.
- In the PDF curve for the 15–11.7 cal kBP interval, the transitions GI-1a/GS-1 and the cooling period GI-1b are clearly marked. However, calibration of date subgroups correlated with warmer periods (**Fig. 4c.1**) and colder periods (**Fig. 4c.2**) allows for more detailed observations:
  - Within GI-1, the dated samples correlate with the cooling periods GI-1d (3 samples) and GI-1c2 (3 samples).
  - The period GI-1b is represented by 11 samples (GI-1c3/GI-1b boundary) and 5 samples (GI-1b/GI-1a boundary).
- The GI-1a/GS1 transition is represented by 4 samples at the end of GI-1a and 7 samples at the beginning of GS-1.
- Within GS-1, a group of 14 dates in the middle of the stadial draws attention, which may indicate the duality of GS-1 and a change in hydrological conditions.

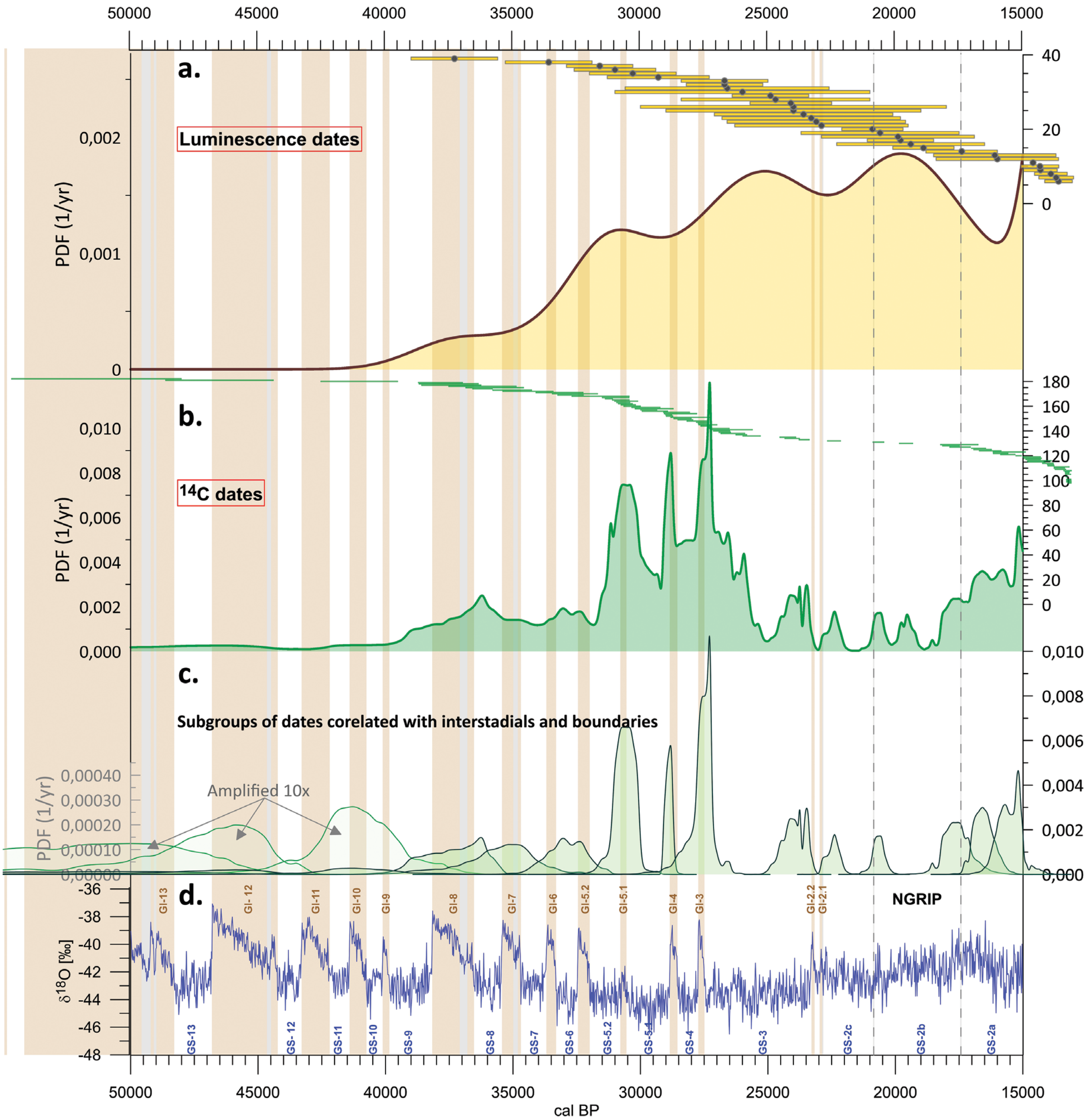

Fig 3*. Curves of PDF for 50–15 cal kBP:* ***(A)*** *– PDF for luminescence dates; in the upper part 68.3% probability ranges for each date are presented in the form of horizontally bars with dots representing medians.* ***(B)*** *– PDF for radiocarbon dates; in the upper part 68.3% probability ranges for each date are presented in the form of horizontally bars.* ***(C)*** *– PDFs for subgroups of radiocarbon dates correlated with interstadials and boundaries. The PDF distribution presented in* ***(B)****. has been divided into distributions for date subgroups. The oldest three dates have large uncertainties and, when presented on the same vertical scale, are almost imperceptible. Therefore, their distributions have been added with an enlarged height of 10× to make it easier to assess where their maxima fall (peaks with green envelope, no fill)* ***(D)*** *– $\delta^{18}O$ data from Greenland ice core (Rasmussen et al., 2014) with marked stadials (GS) and interstadials (GI). GI, Greenland interstadials; GS, Greenland stadials; PDF, probability density function.*

– The GS-1/Holocene transition is recorded by 7 dates at the end of GS-1 and 5 dates at the beginning of the Holocene. Although the Holocene period is beyond the scope of reconstructions, in this article, it is worth noting that the cooling events at 11.4 cal kBP and 9.3 cal kBP are recorded by a group of 5 and 9 dates, respectively.

– The shape of both the summed PDF and the partial PDFs is influenced by the shape of the calibration curve. Especially for younger radiocarbon dates, the stretching

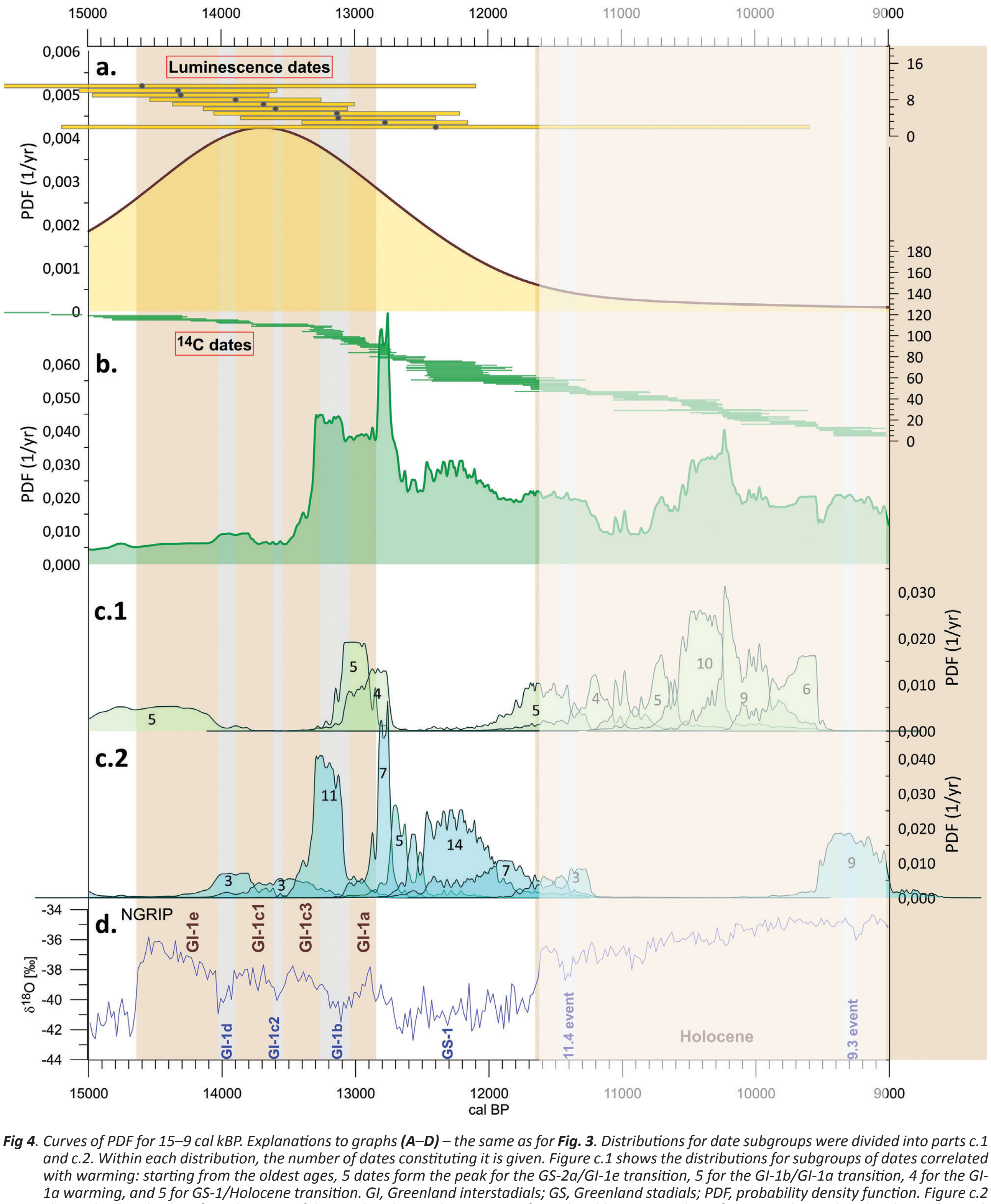

Fig 4. Curves of PDF for 15–9 cal kBP. Explanations to graphs ***(A–D)*** *– the same as for* ***Fig. 3****. Distributions for date subgroups were divided into parts c.1 and c.2. Within each distribution, the number of dates constituting it is given. Figure c.1 shows the distributions for subgroups of dates correlated with warming: starting from the oldest ages, 5 dates form the peak for the GS-2a/GI-1e transition, 5 for the GI-1b/GI-1a transition, 4 for the GI-1a warming, and 5 for GS-1/Holocene transition. GI, Greenland interstadials; GS, Greenland stadials; PDF, probability density function. Figure c.2 shows the distributions for subgroups of dates related to cooling: starting from the oldest ages, 3 dates form a peak correlated with GI-1d, 3 with GI-1c2, 11 with GI-1b, 7 with the GI-1a/GS-1 transition. Within GS-1, there are also peaks created by 5, 14 and 7 dates. Shaded area comprises dates from the beginning of the Holocene added in order to obtain a methodically correct image of the end of Vistulian.*

of individual date groups' distributions can also be attributed to its zigzag pattern.

5. Interpretation and Discussion

The specificity of the fluvial environment makes it possible to study both mineral and organic sediments, and thus the possibility of using available geochronological methods for environmental reconstruction. Such reconstructions are particularly valuable when fluvial sediment sequences contain mineral and organic horizons in superposition. Although the fluvial environment is very sensitive to changes and tends to react dynamically, it has the disadvantage that these features may lead to the destruction of the geological record. Summary of available data from the river valleys of the Łódź region, collected from detailed lithological and structural studies (Turkowska, 1988; Krzyszkowski, 1992; Petera, 2002; Wachecka-Kotkowska, 2004; Forysiak, 2005; Wachecka-Kotkowska *et al*., 2014; Petera-Zganiacz *et al*., 2015; Dzieduszyńska *et al*., 2020) with trends, which are illustrated by PDF curves (**Fig. 5**), gives the opportunity to answer the question about the rank of the signal recorded in the sediment, whether it is local or overregional.

Diversified geological and geomorphological conditions of river valleys in the study area, and thus the presence of sections of different width and depth, determined the characteristics of the components of the accumulation and erosion balance. Sedimentation in the valley system may have been dominated by channel facies or overbank facies deposits, including the formation of extensive floodplain basins. An additional factor influencing accumulation in the river valleys was the supply of wind-transported material. The sediments that entered the valley were then redeposited by the river, which is reflected in the presence of sedimentary structures typical of a fluvial sedimentary environment and a high content of aeolized quartz grains (e.g. Kasse, 2002; Goździk, 2007; Zieliński *et al*., 2015). Moreover, the presence of rivers of various sizes determined the rate of response to environmental variability, i.e. the larger the river, the greater the inertia of the system can be expected. Therefore, not every river had to 'respond' to the change in paleoenvironmental conditions in the same way. For instance, Zieliński *et al*. (2015) found that the course of fluvial-aeolian deposition was asynchronous in time and depended on the local threshold condition in the river basin. It occurred and ceased earlier in small valleys than in the larger ones what resulted from the earlier degradation of permafrost and then from the earlier establishment of the vegetation cover.

The occurrence of organic and organic-mineral horizons in alluvia may be a sign of channel migration or a signal of serious paleoenvironmental changes. Considering the issue discussed, it seems important to stress that we have data from various river valleys in which such horizons appeared. Thus, using the PDF curve of radiocarbon dates, it is possible to determine whether a general trend of paleoenvironmental changes has been registered in a given river valley and whether the formation of the horizon resulted from the local conditions of fluvial processes.

The shape of the PDF curves for the set of luminescence and radiocarbon dates in the period up to about 37.0 cal kBP does not provide information on events in the river valleys of the Łódź region. Fluvial tendencies, interpreted from lithological and structural studies, indicate the dominance of erosion (e.g. Turkowska, 1988; Manikowska, 1996; Wachecka-Kotkowska *et al*., 2014), also reflected in the sedimentary record in the analysed sites presented in this article (**Fig. 2**). This feature applies not only to the Łódź region (e.g. Mol, 1997; Gębica *et al*., 2015; Starkel *et al*., 2015, 2017).

The earliest single dates come from the site of the Parchliny site (>47 cal kBP and 54.7–48 cal kBP; see **Fig. 2**). The first clearer signal of environmental changes occurs around 36.5 cal kBP, which in relation to the Greenland ice-core record locates between GI-8 and GI-7 events. Some geological evidences are available from the Warta valley (Petera, 2002) and the Widawka valley (Krzyszkowski, 1990, 1991, 1992; Kasse *et al*., 1998; Krzyszkowski, 1998; Wachecka-Kotkowska *et al*., 2014), but the current recognition provides no grounds for concluding about common changes in fluvial tendencies in the valleys of the Łódź region (**Fig. 5**).

The cluster of ^{14}C dates occurs *ca*. 30.5 cal kBP, which can be correlated with the GI-5.1 warm event. The next one is at *ca*. 29 cal kBP (GI-4), and the next one is at *ca*. 27.5 cal kBP (GI-3). Comparing the PDF shape with the integrated image of fluvial tendencies shows the existence of a trigger factor during 30.5–27.5 cal kBP. This resulted in multidirectional responses of rivers, manifested, for example, in a change in the components of the erosion/accumulation balance, a change in the channel pattern, or the formation of organic horizons and even peatbogs in the bottoms of river valleys.

A clear decrease in the number of ^{14}C dates in favour of luminescence dates is from 27.5 cal kBP to 17.0 cal kBP. These relationships between the PDFs reflect a change in the river valleys, expressed by a strong aggradation, primarily of mineral sediments, deposited in a braided river regime during the cold maximum in the Upper Plenivistulian; this is particularly visible in the rivers of the Łódź region, which belong to the Odra River catchment.

From about 17.0 cal kBP (the last deglaciation period) the PDF of radiocarbon dates begins to rise. This time

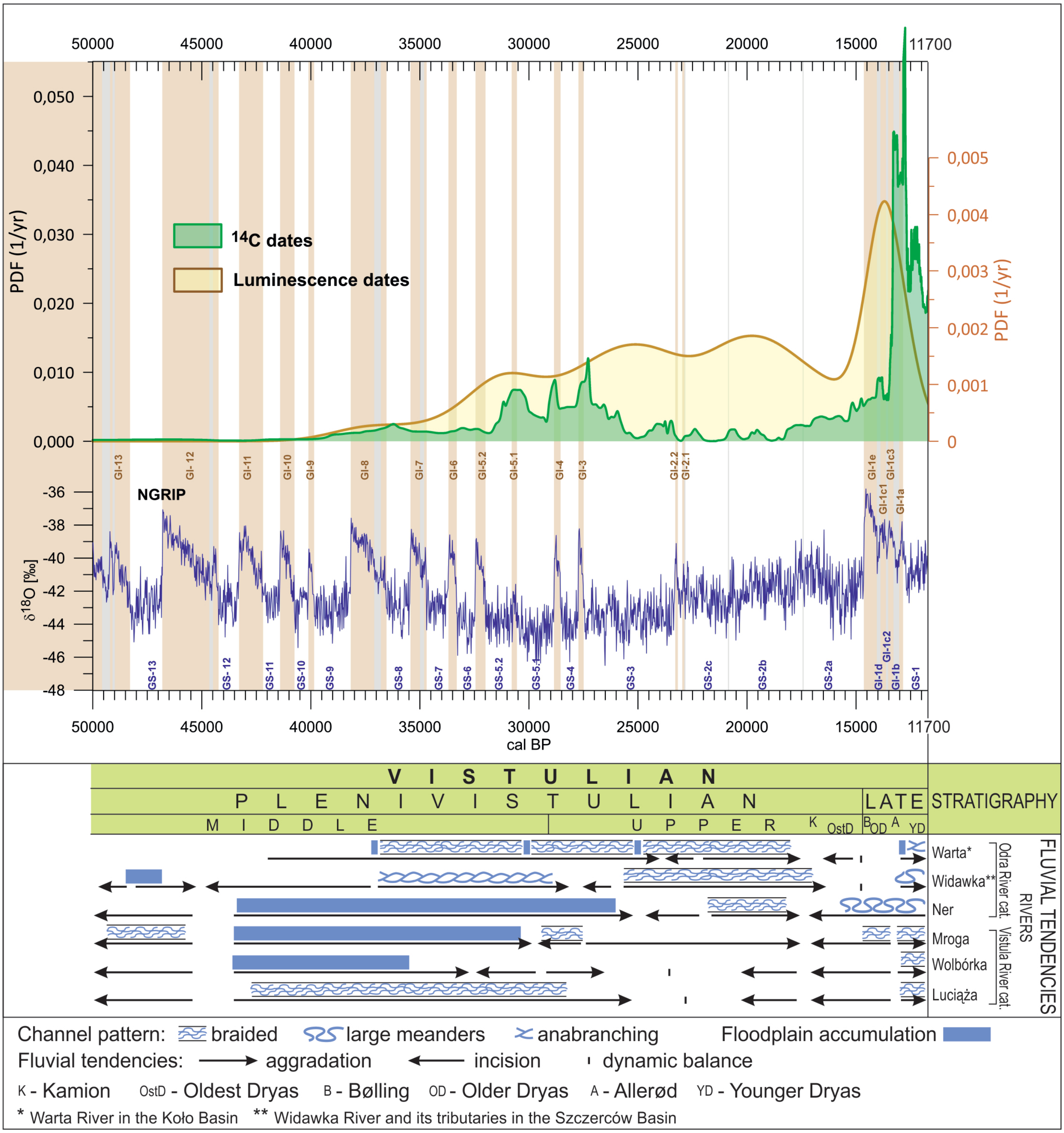

***Fig 5**. Correlation of fluvial activity in selected river valleys from the Łódź region (after Dzieduszyńska et al., 2020, changed and supplemented) with PDF curves and the oxygen curve from the NGRIP core (after Rasmussen et al., 2014). PDF, probability density function.*

seems crucial for the further evolution of the environment of the North Atlantic region because of a large-scale climatic reorganisation at about 16.2 cal kBP, correlated with Heinrich event one (Denton *et al.*, 2010). Isotopic record in Greenland cores has revealed an increase of moisture (d-excess), which is associated with other key environmental changes documented in different parts of the globe (Landais *et al.*, 2018). The expression of these phenomena in Łódź region, and in particular the increase in humidity, is transformation in a fluvial environment. Strong erosion tendencies led to the morphological formation of a high terrace built of Plenivistulian deposits. The changes also concerned the transformation of channel pattern from braided to large meanders (Turkowska, 2006).

The sharp increase in the course of the ^{14}C PDF curve correlates with the Bølling-Allerød warming phase (GI-1). It is preceded by a peak of the PDF luminescence curve (GS-1.c1), which is not explained in the fluvial record. The next section of the PDF for radiocarbon dates reflects the rapid climatic fluctuations of the Late Glacial, also recorded in the Greenlandic core within GI-1, which, due to their short duration, had no chance for response in the fluvial environment attempting to stabilisation as general trend to warming progressed. The large number of ^{14}C attributed to the GS-1 cooling is associated with changes in river valleys towards accumulation, which intensified with time. This resulted in replacing the deposition of organic-mineral sediments in the bottoms of valleys with a deposition dominated by mineral sediments, forming the surface of the low terrace (Petera-Zganiacz *et al*., 2015). This process is not reflected in the PDF for luminescence dates, may be due to rapid redeposition affecting the precision of dating (Dzieduszyńska *et al*., 2014). The response to rapid environmental changes in the valleys of the Łódź region was different as to the channel pattern and resulted from local morphological conditions (Turkowska, 1995; Dzieduszyńska, 2011).

Between 30.5–27.5 cal kBP and 15–11.7 cal kBP, the fluvial environment responded to climate changes in the Northern Hemisphere but the varied responses indicate that these changes were too mild to cause such a consistent response in fluvial trends in the Łódź region as it was in the 27.5–17.0 cal kBP. The results obtained for the Łódź region are currently difficult to compare with the results of research conducted using similar methods in the Carpathian Foreland and the Carpathian Foothills (e.g. Gębica *et al*., 2015; Starkel *et al*., 2015, 2017). Although this area is about 150–250 km away from the Łódź region and has a different morphological characteristics, similar reactions of rivers to overregional paleoenvironmental changes can be expected. However, direct correlations prevent the use of different version of calibration curves.

The limitations of the collective analysis method are related to several factors:

1. Linking dates to dated episodes. The basis of such study is a detailed analysis of source data and the selection of dates for analysis. This factor is the most important. In the case of the analysed region, this stage covers the time period from 2017, when the authors started creating a database for the region. It should be noted that many of the sites included in the study are sites where the authors had already worked much earlier than 2017.
2. The size of the available set of dates. The larger the number, the greater the possibilities of reconstructing past environmental changes. The authors have made every effort to include all age determinations made for the Łódź region in the database.
3. Number of sites. For individual researched sites, there is no continuous record for the time period covered by the research. Hence, the greater the number of sites, the greater the possibility of covering the entire analysed time period with reconstructions. The authors have put every effort to include all investigated sites from the analysed region in the database. The lack of dates from a certain time period may be the result of erosion or too few sites included in the analysis. Therefore, we focus on analysing the peaks of the distribution, not its gaps.
4. Date uncertainties. The greater the uncertainties, the wider the PDF distributions and the more difficult they are to correlate with the INTIMATE stratigraphy. Precise ^{14}C AMS dates are most desirable. The importance of luminescence dates in this type of analyses is much smaller than that of radiocarbon dates. The vast majority of radiocarbon age determinations included were made using conventional techniques and are characterised by greater uncertainties than AMS dates. Certainly, in the future, new ^{14}C age determinations using the AMS technique will contribute to more detailed reconstructions.

6. Conclusion

A comprehensive analysis of ^{14}C age determinations from the Łódź region reveals a correlation between local environmental changes and changes recorded in the NGRIP core. Radiocarbon dating of organic materials associated with fluvial environmental changes indicates that these changes mainly occurred during interstadial periods. Particularly significant changes are observed for interstadials GI-3, GI-4 and GI-5.1. For older periods, we also observe peaks in the PDF distributions, but due to a decrease in the number of dates and increasing uncertainties with age, it becomes more challenging to unambiguously assign them to specific interstadials. Geological data at our disposal are based on sedimentological studies in individual river valleys and were obtained in conditions of obvious limitations resulting from the specificity of the fluvial environment. The course of the PDF curves, in particular, the curve created on the basis of radiocarbon dating and the comparison of its course with the record of changes in the oxygen isotope in the Greenland ice-cores, suggests that there may have been more erosion and accumulation phases. Further work on this topic will be continued, but more precise reconstructions will require studies of new sites and the availability of a greater number of precise age determinations. However, direct correlations prevent the use of different version of the radiocarbon calibration curve in the papers cited above.

Acknowledgements

We would like to thank Prof. Piotr Kittel and Prof. Jacek Forysiak for providing unpublished dates.

Source of Funding

Some dates were obtained as part of the research project No. 2016/21/B//ST10/02451 entitled 'Morphogenetic processes as determinants of vegetation patterns under impact of the Younger Dryas global climatic changes' financed by the National Science Center.

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Supplementary

Database of radiocarbon and luminescence dates for fluvial sediments, Łódź region, central Poland.

No.	Site name / Sample name	Long E	Lat N	Alt. [m a.s.l.]	Dated material	Lab. Code	^{14}C Age [BP]	Dating technique AMS / LSC / GPC	References
1	Aleksandrów (KWB Adamów)	No data	No data	No data	organic silt	Lod 1045	23010±390	LSC	Forysiak J. 2005. Rozwój doliny Warty między Burzeninem i Dobrowem po zlodowaceniu warty. Acta Geographica Lodziensia 90: 5-116. (in Polish, summary in English)
2					organic silt	Lod 1084	24400±470	LSC	
3	Bechcice	No data	No data	No data	peat	IGSB 1381	11020±230	LSC	Stachowicz-Rybka R, Obremska M, Kittel P, Pawłowski D, Cywa K, Forysiak J. 2011. Zapis zmian paleośrodowiskowych w kontekście archeologicznym w osadach wypełnienia paleokoryta w dolinie Neru na stanowisku Kolonia Bechcice (woj. Łódzkie, Polska Środkowa). V Konferencja Paleobotaniki Czwartorzędu, Górzno: 13-17. (in Polish)
4					organic silt	MKL 285	11240±180	LSC	Kittel P. 2012. Budowa i ewolucja doliny Neru w rejonie stanowiska Lutomiersk-Koziówki w świetle badań geoarcheologicznych. Acta Geographica Lodziensia 100:113-133. (in Polish, summary in English)
5	Byszewy	No data	No data	No data	peat	Lod-467	8420±170	LSC	Kamiński J. 1993. Późnoplejstoceńska i holoceńska transformacja doliny Moszczenicy jako rezultat zmian środowiska naturalnego oraz działalności człowieka. Acta Geographica Lodziensia 64. (in Polish, summary in English)
6	Gieczno	No data	No data	No data	organic silt	Lod 437	30500±800	LSC	
7	Głowy	18.67	52.1	96	peat	MKL 1647	10360±70	LSC	Majecka A, Okupny D, Borówka RK, Tomkowiak J, Fortuniak A, Forysiak J, Petera-Zganiacz J, Słowiński M, Krajewska I. 2014. Osady kopalnego starorzecza Warty z późnego vistulianu w odkrywce Koźmin-Głowy (Kotlina Kolska) w świetle wstępnych analiz paleoekologicznych [In:] XXI Konferencja Stratygrafia Plejstocenu Polski "Dynamika lądolodów plejstoceńskich na obszarze Sokólszczyzny i Równiny Augustowskiej", Augustów: 68-69. (in Polish)
8					gyttja	MKL 1649	11120±70	LSC	
9					gyttja	MKL 1648	11260±70	LSC	
10					gyttja	MKL 2311	11350±130	LSC	
11					gyttja	MKL 2312	12140±140	LSC	
12					gyttja	MKL 2313	12350±130	LSC	
13					peat	MKL 1646	9930±60	LSC	
14	Janiszew Poduchowny	18.66	52.09	96.5	peat	Lod 1284	25100±500	LSC	Petera-Zganiacz J. 2007. Stratygrafia osadów vistuliańskich a młodoczwartorzędowa aktywność tektoniczna w okolicach Koźmina. Prace Instytutu Geografii Akademii Świętokrzyskiej w Kielcach 16: 103-116. (in Polish, summary in English)
15		18.65	52.09	96.8	peat	Lod 1392	28330±740	LSC	
16	Kamion	No data	No data	No data	organic silt + peat	Lod 680	11250±170	LSC	Kobojek E. 2000. Morfogeneza doliny Rawki. Acta Geographica Lodziensia 77. (in Polish, summary in English)
17					mud and clay enriched in humus horizon	Gd-4344	13500±290	GPC	Cichosz-Kostecka A, Mycielska-Dowgiałło E, Manikowska B. 1991. Late Glacial aeolian processes in the light of sediment analysis from Kamion profile near Wyszogród. Zeitschrift für Geomorphologie, Suppl.-Bd. 90: 45-50.
18					mud and clay enriched in humus horizon	Gd-4343	14300±300	GPC	
19		20.18	52.35	No data	mud and clay enriched in humus horizon	Lod 85	14590±270	LSC	Manikowska B. 1985. O glebach kopalnych, stratygrafii i litologii wydm Polski środkowej. Acta Geographica Lodziensia 52. (in Polish, summary in English)
20	Kolonia Bechcice	No data	No data	No data	decomposed peat	IGSB-1382	8250±150	LSC	Kittel P., 2014. Slope deposits as an indicator of anthropopressure in the light of research in Central Poland. Quaternary International 324: 34-55.
21					organic mud	Lod-1441	9020±80	LSC	

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No.	Site name / Sample name	Long E	Lat N	Alt. [m a.s.l.]	Dated material	Lab. Code	^{14}C Age [BP]	Dating technique AMS / LSC / GPC	References
22	Kolonia Bechcice	19.23	51.75	No data	decomposed peat	Poz-41755	9090±50	AMS	Płóciennik M., Kittel P., Borówka R.K., Cywa K., Okupny D., Obremska M., Pawłowski D., Stachowicz-Rybka R., Szperna R., Witkowski A., *et al*. 2016. Warunki paleoekologiczne subkopalnego koryta Kolonia Bechcice na tle hydrologii środkowego odcinka doliny Neru. Acta Geographica Lodziensia 105: 107-124. (in Polish, summary in English)
23					gyttja	MKL-417	9520±90	LSC	
24		No data	No data	No data	organic silt	IGSB-1384	9120±440	LSC	unpublished
25	Koźmin JPII/I	No data	No data	No data	organic silt with charcoal	MKL-1388	9240±80	LSC	unpublished
26	Koźmin-KN	18.67	52.10	96.0	gyttja	MKL-4276	8380±100	LSC	unpublished
27					gyttja	MKL-4277	8740±90	LSC	
28					gyttja	MKL-3336	9310±80	LSC	
29					gyttja	MKL-3373	8270±100	LSC	
30	Koźmin-Las	18.67	52.08	97.5	organic matter in sandy silt	MKL-1077	9780±110	LSC	Dzieduszyńska D, Petera-Zganiacz J, Twardy J, Kittel P, Moska P and Adamiec G, 2014a. Optical dating and sedimentary record from the terrace depositional profile of the Warta River (central Poland). Geochronometria 41(4): 361–368.
31		18.67	52.08	97.5	organic silt	MKL-1076	9780±150	LSC	
32		18.67	52.08	97.5	plant remains: Betula sect. Albae - 2 fruit scales	Poz 50361	10000±80	AMS	
33		18.67	52.08	97.5	plant remains: Betula sect. Albae - 2 fruit scales; Pinus Sylvestris - 1 shoot	Poz 50360	10430±80	AMS	
34		18.67	52.08	97.5	plant remains: Pinus sylvestris - shoots & fragment of needle	Poz 50356	10850±60	AMS	
35	Koźmin	18.67	52.08	97.5	charcoal in flood sediments	GdA-6077	10480±50	AMS	unpublished
36		18.65	52.08	97.5	organic silt	Gd-9740	10200±430	GPC	Petera-Zganiacz J, Dzieduszyńska D. 2007. Wymowa paleogeograficzna horyzontu pni kopalnych w osadach późnego vistulianu. Acta Geographica Lodziensia 93: 57-66. (in Polish, summary in English)
37		18.65	52.09	97	organic silt	Lod 1389	10350±90	LSC	
38		No data	No data	No data	organic silt	Lod-661	8250±120	LSC	Petera J. 2002. Vistuliańskie osady dolinne w basenie uniejowskim i ich wymowa paleogeograficzna. Acta Geographica Lodziensia 83. (in Polish, summary in English)
39		No data	No data	No data	peat	Lod 974	11980±110	LSC	MAiE archives
40		18.61	52.03	107	organic silt	MKL 4275	12420±130	LSC	unpubished
41		18.66	52.08	97.5	peat	Lod 768	18480±230	LSC	Petera J. 2002. Vistuliańskie osady dolinne w basenie uniejowskim i ich wymowa paleogeograficzna. Acta Geographica Lodziensia 83. (in Polish, summary in English)
42		18.65	52.08	97	organic silt	Lod 659	24200±300	LSC	
43		18.66	52.08	97.5	organic silt	Lod 769	29950±900	LSC	
44		18.67	52.09	97	organic silt	Lod 1403	31280±1050	LSC	Petera-Zganiacz J, Adamiec G. 2010. The age of the Warta river valley deposits based on ^{14}C, TL, OSL dating methods (Kotlina Kolska, Middle Poland). 10th International Conference "Methods of Absolute Chronology". 22-25 April 2010, Gliwice, Poland: 112.

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No.	Site name / Sample name	Long E	Lat N	Alt. [m a.s.l.]	Dated material	Lab. Code	^{14}C Age [BP]	Dating technique AMS / LSC / GPC	References
45	Koźmin Północ	18.66	52.08	97	organic silt	Lod 879	26290±560	LSC	Petera J. 2002. Vistuliańskie osady dolinne w basenie uniejowskim i ich wymowa paleogeograficzna. Acta Geographica Lodziensia 83. (in Polish, summary in English)
46					organic silt	Lod 878	31740±1100	LSC	
47					organic silt	Lod 881	36310±1860	LSC	
48	Koźmin Środkowy	18.67	52.08	97.5	organic silt	Lod 700	28600±260	LSC	Petera J. 2002. Vistuliańskie osady dolinne w basenie uniejowskim i ich wymowa paleogeograficzna. Acta Geographica Lodziensia 83. (in Polish, summary in English)
25	Koźmin-Kwiatków	No data	No data	No data	organic silt	GdS-4021	9980±100	LSC	unpublished
49		18.68	52.10	96.5	organic silt	GdS-4062	10600±90	LSC	
51		18.68	52.10	96.3	organic silt	GdS-4030	9990±90	LSC	
52					organic silt	GdS-4048	10380±260	LSC	
53	Krzeczów	No data	No data	No data	peat	Lod-365	9080±150	LSC	Kanwiszer A, Trzeciak P. 1991. Lodz radiocarbon dates III. Radiocarbon 33(1): 115-130.
54	Kwiatków	18.68	52.1	96.5	organic silt	MKL 1644	10940±100	LSC	Petera-Zganiacz J, Piotrowska M, Twardy J, Dzieduszyńska DA, Okupny D, Forysiak J, Rzepecki S. 2019a. Environmental conditions as a key factor in the functioning of wells at a settlement from the Roman period of the Iron Age. Quaternary International 501: 250-268.
55					organic silt	MKL 1645	10960±100	LSC	
56	Kwiatków DJ	18.68	52.1	96	organic silt	MKL 3335	10720±100	LSC	Dzieduszyńska DA, Petera-Zganiacz J. 2018. Small-scale geologic evidence for Vistulian decline cooling periods: case studies from the Łódź Region (Central Poland). Bulletin of the Geological Society of Finland 90(2): 209-222.
57	Lublinek	No data	No data	No data	organic silt	Gd-9196	10220±170	LSC	Turkowska K, Dzieduszyńska D. 2011. Local evidence of landform evolution vs. global changes – a case of Younger Dryas study in the upper Ner valley system, central Poland. Geographia Polonica 84, Special Issue 1: 147-162.
58					organic silt	Gd-10027	10690±140	LSC	
59					organic layer	Lod 444	11320±160	LSC	
60					organic mud	Lod 479	12470±180	LSC	Turkowska K. 1988. Rozwój dolin rzecznych na Wyżynie Łódzkiej w późnym czwartorzędzie. Acta Geographica Lodziensia 57. (in Polish, summary in English)
61		19.35	51.73	No data	organic silt	Lod 238	12950±390	LSC	
62		19.35	51.73	No data	organic silt in situ	Lod 370	13800±200	LSC	
63		No data	No data	No data	organic mud	Lod 445	16200±200	LSC	Turkowska K, Dzieduszyńska D. 2011. Local evidence of landform evolution vs. global changes – a case of Younger Dryas study in the upper Ner valley system, central Poland. Geographia Polonica 84, Special Issue 1: 147-162.
64					organic mud	Lod 478	17100±200	LSC	
65					organic detritus	Gd-1906	21720±220	GPC	Turkowska K. 1988. Rozwój dolin rzecznych na Wyżynie Łódzkiej w późnym czwartorzędzie. Acta Geographica Lodziensia 57. (in Polish, summary in English)
66		19.35	51.73	No data	organic silt	Lod 275	9850±250	LSC	
67		No data	No data	No data	organic detritus	Gd-7541	9470±40	LSC	
68					organic detritus	Lod 274	9380±250	LSC	Turkowska K. 1988. Rozwój dolin rzecznych na Wyżynie Łódzkiej w późnym czwartorzędzie. Acta Geographica Lodziensia 57.
69					organic detritus	Gd-10099	9200±90	GPC	Turkowska K, Dzieduszyńska D. 2011. Local evidence of landform evolution vs. global changes – a case of Younger Dryas study in the upper Ner valley system, central Poland. Geographia Polonica 84, Special Issue 1: 147-162.

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No.	Site name / Sample name	Long E	Lat N	Alt. [m a.s.l.]	Dated material	Lab. Code	^{14}C Age [BP]	Dating technique AMS / LSC / GPC	References
70	Lublinek	No data	No data	No data	poorly decomposed peat	Gd-2410	8400±200	GPC	Turkowska K. 1988. Rozwój dolin rzecznych na Wyżynie Łódzkiej w późnym czwartorzędzie. Acta Geographica Lodziensia 57. (in Polish, summary in English)
71					organic layer	Lod 342	8350±160	LSC	Turkowska K. 1988. Rozwój dolin rzecznych na Wyżynie Łódzkiej w późnym czwartorzędzie. Acta Geographica Lodziensia 57. (in Polish, summary in English)
72					organic layer	Lod 373	8250±150	LSC	
73					pine cone	Gd-1839	8240±160	GPC	Turkowska K. 1988. Rozwój dolin rzecznych na Wyżynie Łódzkiej w późnym czwartorzędzie. Acta Geographica Lodziensia 57. (in Polish, summary in English)
74					organic layer	Lod 276	8180±220	GPC	Turkowska K. 1990. Main fluvial episodes in the Ner Valley in the last 22 000years; a detailedin Lublinek near Łódź, Central Poland. Quaternary Studies in Poland 9: 85-89.
75	Lutomiersk-Koziówki	No data	No data	No data	organic silt with plant detritus	MKL-286	9240±120	LSC	Kittel P. 2012. Budowa i ewolucja doliny Neru w rejonie stanowiska Lutomiersk-Koziówki w świetle badań geoarcheologicznych. Acta Geographica Lodziensia 100: 113-133. (in Polish, summary in English)
76					peat	MKL-287	8670±70	LSC	
77					peat	MKL-284	9030±160	LSC	
78					organic silt with plant detritus	MKL-283	9240±120	LSC	
79	Łęg Ręczyński	19.22	51.23	No data	peat	Lod 328	10270±220	LSC	Kanwiszer A, Trzeciak P. 1986. Lodz radiocarbon dates II. Radiocarbon 28(3): 1102-1109.
80	Łykowe	18.78	51.2	No data	sandy peat	Lod-150	8070±180	LSC	Kanwiszer A, Trzeciak P. 1991. Lodz radiocarbon dates III. Radiocarbon 33(1): 115-130.
81					sandy peat	Lod-149	9150±210	LSC	
82					organic silt	Lod 148	10380±220	LSC	MAiE archives
83					peat	Lod 358	11700±200	LSC	
84	Majkowice	No data	No data	No data	peat	Gd-2044	13030±200	GPC	Szumański A. 1983. Palaeochannelsof large meandersin the river valley of the Polish Lowland. Quaternary Studies in Poland 4: 207-16.
85	Paskrzyn	19.87	51.23	182.5	choarcoal	Lod 263	11600±300	LSC	MAiE archives
86		19.87	51.23	No data	organic silt	Lod 244	12250±190	LSC	
87		19.87	51.23	183	sandy silt with plant detritus	Lod 262	13200±200	LSC	
88	Polesie	No data	No data	No data	sand and silty sand	Lod-1380	21990±350	LSC	Twardy J. 2008. Transformacja rzeźby centralnej części Polski Środkowej w warunkach antropopresji. Łódź: Wydawnictwo Uniwersytetu Łódzkiego. (in Polish)
89	Przedbórz	19 53 00	51 03 00	190	peat	Gd-1468	8890±60	GPC	Szumański A. 1983. Paleochannels of the large meanders in the river valleys of the Polish Lowland. Quaternary Studies in Poland 4: 207-216.
90	Rogóźno	No data	No data	No data	plant remains	Lod-442	8950±180	LSC	Kamiński J. 1993. Późnoplejstoceńska i holoceńska transformacja doliny Moszczenicy jako rezultat zmian środowiska naturalnego oraz działalności człowieka. Acta Geographica Lodziensia 64. (in Polish, summary in English)
91					plant remains	Lod-443	8700±160	LSC	
92					organic silt	Lod 411	10400±200	LSC	

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No.	Site name / Sample name	Long E	Lat N	Alt. [m a.s.l.]	Dated material	Lab. Code	^{14}C Age [BP]	Dating technique AMS / LSC / GPC	References
93	Rozprza	19.67	51.3	183	macrofossils in organic mud; Pinus sylvestris - 22 shoots and 2 needles; Betula sect. albae - 1 fruit scale and 1 fruit; Betula nana - 3 fruits	MKL-A4682	10069±27	AMS	unpublished
94					gyttja	MKL-2408	10200±120	LSC	Kittel P, Sikora J, Woroniecki P. 2018. A Late Medieval motte-and-bailey settlement in a lowland river valley landscape of Central Poland. Geoarchaeology 33: 558-578.
95					clayey gyttja	MKL-2818	10380±70	LSC	
96					macrofossils in coarse detritus gyttja with sandy admixtures: Pinus sylvestris - 8 shoots and 5 bud scales; shrub buds undif. - 5; Betula sect. albae - 4 fruit scales	MKL-A3933	10415±26	AMS	
97					gyttja	MKL-2959	10810±90	LSC	
98					macrofossils in coarse detritus gyttja: Pinus sylvestris – fragments of needle	MKL-A3566	10877±31	LSC	
99					macrofossils in peaty organic mud: Pinus sylvestris - 20 shoots; Betula sect. albae - 2 fruit scales and 3 fruits; Betula nana - 4 fruit scales and 2 fruits; Filipendula ulmaria - 1 seed; Urtica dioica - 1 seed	MKL-A4681	10889±35	AMS	
100					gyttja	MKL-2960	10930±100	LSC	
101					peaty organic mud; Pinus sylvestris - 2 seeds and 20 shoots; Betula sect. albae - 2 fruit scales; Carex sp. trigonous - 1 fruit	MKL-A3934	11029±26	LSC	
102					clayey organic mud	MKL-2819	11070±80	LSC	

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No.	Site name / Sample name	Long E	Lat N	Alt. [m a.s.l.]	Dated material	Lab. Code	^{14}C Age [BP]	Dating technique AMS / LSC / GPC	References
103					macrofossils in organic mud: Pinus sylvestris - 1 fragment of cone, 5 shoots and 2 fragments of needle; Betula sect. albae - 2 fruit scales and 5 fruits; Betula nana - 7 fruit scales and 6 fruits	MKL-3503A	11126±82	AMS	
104					macrofossils in organic mud: Pinus sylvestris - 4 fragments of cone and 3 bud scales; Betula sect. albae - 2 fruit scales	MKL-A3935	11404±27	AMS	
105					clayey organic mud	MKL-2961	12010±120	LSC	
106					laminated organic mud	MKL-2820	12720±80	LSC	
107	Swędów JK	No data	No data	No data	peat	Lod-303	8740±110	LSC	Kamiński J. 1989. Wpływ holoceńskich procesów eolicznych na kształtowanie dna doliny Moszczenicy. Acta Geographica Lodziensia 59:11-17.
108					peat	Lod 339	32800±900	LSC	Kamiński J. 1993. Późnoplejstoceńska i holoceńska transformacja doliny Moszczenicy jako rezultat zmian środowiska naturalnego oraz działalności człowieka. Acta Geographica Lodziensia 64.
109				146	organic silt	Lod 286	10370±250	LSC	
110					organic silt	Lod 304	10850±180	LSC	
111	Swędów	19.52	51.92	145	organic silt	GdS 3963	11390±100	LSC	Petera-Zganiacz J, Dzieduszyńska DA, Forysiak J, Twardy J, Milecka K, Czerwiński B. 2019b. The Late Vistulian record in deposits of the Moszczenica River valley at the Swędów site (Central Poland). [In:] Börner A. Hüneke H. Lorenz S. (Eds.) Field Symposium of the INQUA PeriBaltic Working Group "From Weichselian Ice-Sheet Dynamics to Holocene Land Use Development in Western Pomerania and Mecklenburg". Abstract Volume. Scientific Technical Report STR 19/01, Potsdam: GFZ German Research Centre for Geosciences:74-76. DOI: http://doi.org/10.2312/GFZ.b103-19012
112					organic silt	GdS 3970	11410±65	LSC	
113					organic silt, rejuvenated date, not analysed	GdS-3983	8980±95	LSC	
114	Swędów II	19.52	51.92	146,25	organic silt	GdA-6444	10660±60	AMS	unpublished
115	Świerczyna	No data	No data	No data	wood	Poz-52513	8060±90	AMS	Pawłowski D, Płóciennik M, Brooks SJ, Luoto TP, Milecka K, Nevalainen L, Peyron O, Self A, Zieliński T. 2015. A multiproxy study of Younger Dryas and Early Holocene climatic conditions from the Grabia River paleo-oxbow lake (central Poland). Palaeogeography, Palaeoclimatology, Palaeoecology 438: 34-50.
116					stems of moss	Poz-54910	9500±50	AMS	
117		19.01	51.47	94	plant remains	Poz 52514	10010±70	AMS	
118					plant remains	Poz 54911	10150±90	AMS	
119					plant remains	Poz 54915	10250±110	AMS	
120					plant remains	Poz 54914	10360±60	AMS	
121					plant remains	Poz 54913	10370±80	AMS	
122					plant remains	Poz 52516	10420±60	AMS	

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No.	Site name / Sample name	Long E	Lat N	Alt. [m a.s.l.]	Dated material	Lab. Code	^{14}C Age [BP]	Dating technique AMS / LSC / GPC	References
123	Troniny	18.75	51.1	No data	organic silt	Lod 357	10710±180	LSC	MAiE archives
124	Tum	No data	No data	No data	peat	Lod-1558	8650±80	LSC	Marosik P, Forysiak J. 2014. Ukształtowanie terenu, budowa geologiczna i rozwój paleogeograficzny otoczenia grodziska w Tumie. [In:] Grygiel R, Jurek T (eds.), Początki Łęczycy. Archeologia środowiskowa średniowiecznej Łęczycy, t. I. MAiE, Łódź: 59-94. (in Polish)
125					peat	Lod-1499	8790±80	LSC	
126					organic silt	Lod-1598	8950±80	LSC	
127					peat	Lod-1596	9010±80	LSC	
128					organic silt	Lod-1588	9190±80	LSC	
129					organic silt	Lod-1595	9250±80	LSC	
130					peaty silt	Lod-1590	9490±90	LSC	
131					peaty gyttja	Lod-1589	9770±90	LSC	
132					gyttja	Lod 1560	10190±90	LSC	
133					organic silt	Lod 1592	10210±90	LSC	
134					peat	Lod 1599	10390±90	LSC	
135					peat	Lod 1591	10870±100	LSC	
136					gyttja	Lod 1498	10880±100	LSC	
137					gyttja	Lod 1549	11270±100	LSC	
138					gyttja	Lod 1593	11280±100	LSC	
139					gyttja	Lod 1559	11290±100	LSC	
140	Warenka	18.61	52.03	107	organic silt	MKL 4280	19970±260	LSC	unpublished
141					organic silt	MKL 4278	22540±210	LSC	
142					organic silt	MKL 4279	23170±230	LSC	
143		18.63	52.05	105	organic silt	GdA-6445	22370±150	AMS	
144					organic silt	GdA-6446	19580±120	AMS	
145					organic silt	GdA-6447	25460±200	AMS	
146	Warszyce	No data	No data	No data	peat	Lod-469	8900±170	LSC	Kamiński J. 1993. Późnoplejstoceńska i holoceńska transformacja doliny Moszczenicy jako rezultat zmian środowiska naturalnego oraz działalności człowieka. Acta Geographica Lodziensia 64. (in Polish, summary in English)
147					organic silt	Lod 439	28900±700	LSC	
148	Wierzbowa	19.08	51.97	112-116	organic mud	Lod-1450	9270±80	LSC	Kittel P., 2014. Slope deposits as an indicator of anthropopressure in the light of research in Central Poland. Quaternary International 324: 34-55.
149	Parchliny A (PARCH 3)	19.14	51.23	175.5	organic horizon in sandy-muddy deposits	GdS-1128	43500 ± 2000	LSC	Wachecka-Kotkowska L, Krzyszkowski D, Klaczak K, Król E, 2014. Middle Weichselian pleniglacial sedimentation in the Krasówka river palaeovalley, Central Poland. Annales Societatis Geologorum Poloniae 84(4): 323–340.
150	Parchliny A PARCH 2)	19.14	51.23	163.9	peat; middle part of organic horizon	GdS-1127	47500 ± 3500	LSC	
151	Parchliny B (PARCH 4)	19.15	51.23	164.4	organic horizon in sand-mud	GdS-1366	33090 ± 580	LSC	
152	Parchliny B (PARCH5)	19.15	51.23	165.7	organic horizon in sand-mud	GdS-1371	24080 ± 250	LSC	

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No.	Site name / Sample name	Long E	Lat N	Alt. [m a.s.l.]	Dated material	Lab. Code	^{14}C Age [BP]	Dating technique AMS / LSC / GPC	References
153	Folwark 1; B/2691			192	humic acids	GrN-18148	23370 ± 250	AMS	Kasse C, Huijzer AS, Krzyszkowski D, Bohncke SJP and Coope GR. 1998. Weichselian Late Pleniglacial and Late-glacial depositional environments, Coleoptera and periglacial climatic records from central Poland (Betchatow). Journal of Quaternary Science 13(5): 455–469.
154				197	organic deposits	GrN-18147	24630 ± 110	AMS	Kasse C, Huijzer AS, Krzyszkowski D, Bohncke SJP and Coope GR. 1998. Weichselian Late Pleniglacial and Late-glacial depositional environments, Coleoptera and periglacial climatic records from central Poland (Betchatow). Journal of Quaternary Science 13(5): 455–469.
155	Folwark 1; B/2692			192	humic acids	GrN-20387	22730 ± 250	AMS	Kasse C, Huijzer AS, Krzyszkowski D, Bohncke SJP and Coope GR. 1998. Weichselian Late Pleniglacial and Late-glacial depositional environments, Coleoptera and periglacial climatic records from central Poland (Betchatow). Journal of Quaternary Science 13(5): 455–469.
156					humic acids	GrN-18150	23400 ± 320	AMS	
157		19.29	51.25	197	organic deposits	GrN-18149	24590 ± 120	AMS	Krzyszkowski D. 1998. Stratigraphy and sedimentology of Weichselian deposits at Folwark, Belchatów outcrop, central Poland. Quaternary Studies in Poland 15: 3-26.
158	Folwark 2; B/2695			197	organic deposits	GrN-18155	25970 ± 220	AMS	Kasse C, Huijzer AS, Krzyszkowski D, Bohncke SJP and Coope GR. 1998. Weichselian Late Pleniglacial and Late-glacial depositional environments, Coleoptera and periglacial climatic records from central Poland (Betchatow). Journal of Quaternary Science 13(5): 455–469.
159					organic deposits	GrN-20388	26320 ± 270	AMS	
160					organic deposits	GrN-18156	27190 ± 200	AMS	
161					organic deposits	GrN-20529	27270 ± 750	AMS	
162	Folwark 2; B/2696				organic deposits	GrN-20528	21420 ± 350	AMS	
163					organic deposits	GrN-18158	26190 ± 270	AMS	
164					organic deposits	GrN-18157	26430 ± 240	AMS	
165					organic deposits	GrN-20389	26620 ± 360	AMS	
166	Folwark 8; B/2742	19.27	51.22	199	plant macrofossils	GrA-3016	22990 ± 120	AMS	
167	Kuców C-I	No data	No data	No data	organic material in loam	Lod-738	31860 ± 350	LSC	Trzeciak P, Borowiec I. 2013. Oznaczanie chronologii bezwzględnej metodą radiowęglową w Pracowni Muzeum Archeologicznego i Etnograficznego w Łodzi. Prace i Materiały Muzeum Archeologicznego i Etnograficznego w Łodzi, Seria Numizmatyczno- Konserwatorska. (in Polish)
168	Kuców C-III	No data	No data	No data	organic material in silt/clay	Lod-746	25620 ± 540	LSC	MAiE archives

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No.	Site name / Sample name	Long E	Lat N	Alt. [m a.s.l.]	Dated material	Lab. Code	^{14}C Age [BP]	Dating technique AMS / LSC / GPC	References
169	Stawek γ-96	No data	No data	No data	organic material in silty sand	Lod-737	20170 ± 250	LSC	Trzeciak P, Borowiec I. 2013. Oznaczanie chronologii bezwzględnej metodą radiowęglową w Pracowni Muzeum Archeologicznego i Etnograficznego w Łodzi. Prace i Materiały Muzeum Archeologicznego i Etnograficznego w Łodzi, Seria Numizmatyczno- Konserwatorska. (in Polish)
170	No data	No data	No data	No data	unknow	unknow	23700 ± 800	LSC	Manikowska B. 1996. Dwucykliczność ewolucji środowiska peryglacjalnego w Polsce Środkowej podczas vistulianu. Biuletyn Państwowego Instytutu Geologicznego 373: 97-106. (in Polish, summary in English)
171	Bełchatów	No data	No data	No data	organic mud	Gd-2640	12440 ± 180	GPC	Goździk, JS. 1995b. Vistulian sediments in the Bełchatów open cast mine, Central Poland. Qualernary Studies in Poland 13: 13-26.
172					organic mud	Gd-4348	13670 ± 240	GPC	
173	Bełchatów Piaski	No data	No data	No data	plant remains	Lod 116	14350 ± 580	LSC	Goździk J. 1980. Osady i struktury peryglacjalne z plejstocenu okolic Bełchatowa. Przewodnik LIII, Zjazdu Polskiego Towarzystwa Geologicznego. Wydawnictwa Geologiczne, Waszawa: 322-325. (in Polish)
174	Bełchatów JG/82	No data	No data	No data	organic materials in silt	Gd-2035	11630 ± 180	GPC	French HM, Goździk JS 1988. Pleistocene epigenetic and syngenetic frost fissures, Bełchatów, Poland. Canadian Journal of Earth Science 25(12): 2017-2027.
175	Bełchatów profile B; kopalnia-D	No data	No data	No data	peat	Lod-317	32700 ± 900	LSC	Kanwiszer A, Trzeciak P. 1991. Lodz radiocarbon dates III. Radiocarbon 33(1): 115-130.
176	Bełchatów; I/83/JG	51.25	19.38		peat	Gd-1707	11170 ± 110	GPC	Michczyńska D.J., Dzieduszyńska D.A., Petera-Zganiacz J., Wachecka-Kotkowska L., Krzyszkowski D., Wieczorek D., Ludwikowska-Kędzia M., Gębica P. Starkel L., 2022. Climatic oscillations during MIS 3-2 recorded in sets of ^{14}C and OSL dates - a study based on data from Poland. Radiocarbon 64(6): 1373-1386.
177	BełchatówII/83/JG	19.38	51.25		peat	Gd-2189	10160 ± 140	GPC	
178	Piaski 3	No data	No data	No data	organic material in ooze formation	Lod-118	25200 ± 740	LSC	Goździk J. 1980. Osady i struktury peryglacjalne z plejstocenu okolic Bełchatowa. Przewodnik LIII, Zjazdu Polskiego Towarzystwa Geologicznego. Wydawnictwa Geologiczne, Waszawa: 322-325.
179	Piaski prof 1/061077	No data	No data	No data	peat	Gd-777	21970 ± 810	GPC	Goździk J. 1986. Czwartorzęd w regionie kopalnie węgla brunatnego, Bełchatów. II Zjazd Geografów Polskich, Łódź, 11 - 13 września, 1986. Przewodnik wycieczek: 109-114. (in Polish)
180	Widawka valley	No data	No data	No data	organic layer	Gd-5484	23600 ± 400	GPC	Goździk, JS. 1995b. Vistulian sediments in the Bełchatów open cast mine, Central Poland. Qualernary Studies in Poland 13: 13-26.
181					organic layer	Gd-6003	24200 ± 650	GPC	
182					organic layer	Gd-5485	26900 ± 500	GPC	

No.	Site name / Sample name	Long E	Lat N	Alt. [m a.s.l.]	Dated material	Lab. Code	Luminescence age [BP]	Technique TL/OSL	References
1	Chałupki k/ Przedborza	51.07	19.88	no data	sand (fluvial)	PIG238	24000 ± 5000	OSL	Wieczorek D, Stoiński A, Zabielski R, 2019. Objaśnienia do Szczegółowej mapy geologicznej Polski w skali 1:50 000, arkusz Przedbórz (775). (Explanations to the Detailed Geological Map of Poland in the scale 1:50,000, Przedbórz sheet (775)). (in Polish) NAG, PIG-PIB Warszawa (electronical version).
2					sand (fluvial)	PIG237	24000 ± 6000	OSL	
3					sand (fluvial)	PIG239	26000 ± 5000	OSL	
4	Koźmin	18.67	50.08	97	sand (fluvial)	GdTL-1410	12780 ± 620	OSL	Dzieduszyńska D., Petera-Zganiacz J., Twardy J., Kittel P., Moska P., Adamiec G., 2014b – Optical dating and sedimentary record from the terrace depositional profile of the Warta River (Central Poland). Geochronometria, 41(4); 361-368
5					sand (fluvial)	GdTL-1412	13130 ± 730	OSL	
6					sand (fluvial)	GdTL-1413	13140 ± 920	OSL	
7					sand (fluvial)	GdTL-1516	13690 ± 680	OSL	
8			52.09		sand (fluvial)	GdTL 925	13900 ± 640	OSL	
9			50.08		sand (fluvial)	GdTL-1515	14310 ± 660	OSL	
10					sand (fluvial)	GdTL-1517	14330 ± 740	OSL	
11			52.09		sand (fluvial)	GdTL 924	31000 ± 1600	OSL	Petera-Zganiacz J, Adamiec G. 2010. The age of the Warta river valley deposits based on 14C, TL, OSL dating methods (Kotlina Kolska, Middle Poland). 10th International Conference “Methods of Absolute Chronology”. 22-25 April 2010, Gliwice, Poland: 112.
12					sand (fluvial)	GdTL 923	31600 ± 1300	OSL	
13			52.08		sand (fluvial)	GdTL 987	33600 ± 1700	OSL	
14			52.09		sand (fluvial)	GdTL 922	37300 ± 1700	OSL	
15	Kolonia Bechcice	no data	no data	no data	sand (fluvial)	GW-1126	16000 ± 2400	TL	Kittel P. 2012. Budowa i ewolucja doliny Neru w rejonie stanowiska Lutomiersk-Koziówki w świetle badań geoarcheologicznych. Acta Geographica Lodziensia 100:113-133. (in Polish, summary in English)
16					sand (fluvial)	GW 1125	16100 ± 2400	TL	
17					sand (fluvial)	GW-1124	19400 ± 2900	TL	
18					sand (fluvial)	GW-0802	23600 ±3500	TL	
19					sand (fluvial)	GW-0801	26600 ± 4000	TL	
20	Rozprza	19.67	51.3	183	sand (fluvial)	UJK-OSL-72	24700 ± 3700	OSL	Sikora J, Kittel P, Frączek M, Głąb Z, Golyeva A, Mueller-Bieniek A, Schneeweiß J, Tomczyńska Z, Wasylikowa K, Wiedner K. 2019. A palaeoenvironmental reconstruction of the rampart construction of the medieval ring-fort in Rozprza, Central Poland. Archaeological and Anthropological Sciences 11:4187-4219.
21	Szynkielew	no data	no data	no data	sand (fluvial)	no data	19900±3000	TL	Kittel P., 2016. Badania geoarcheologiczne pokrywy stokowej na stanowisku archeologicznym Szynkielew 11, gm. Pabianice. Acta Universitatis Lodziensis. Folia Geographica Physica 15: 25-35. (in Polish, summary in English)
22					sand (fluvial)		20600±3100	TL	
23	Warenka	18.62	52.04	105	sand (fluvial)	GdTL-3440	17400 ± 1400	OSL	unpublished
24		18.62	52.04	105	sand (fluvial)	GdTL-3529	24100 ± 1600	OSL	
25		18.62	52.04	105	sand (fluvial)	GdTL-3530	24900 ± 1500	OSL	
26		18.61	52.03	105	sand (fluvial)	GdTL-3177	26700 ± 1500	OSL	
27		18.62	52.04	105	sand (fluvial)	GdTL-3531	26700 ± 1700	OSL	
28	Warenka	18.62	52.04	105	sand (fluvial)	GdTL-3532	29300 ± 2000	OSL	unpublished
29		18.61	52.03	105	sand (fluvial)	GdTL-3178	30300 ± 1700	OSL	
30	Swędów	51.92	19.53	145	sand (fluvial)	GdTL-3140	18900±1200	OSL	Michczyńska D.J., Dzieduszyńska D.A., Petera-Zganiacz J., Wachecka-Kotkowska L., Krzyszkowski D., Wieczorek D., Ludwikowska-Kędzia M., Gębica P. Starkel L., 2022. Climatic oscillations during MIS 3-2 recorded in sets of 14C and OSL dates - a study based on data from Poland. Radiocarbon 64(6): 1373-1386.
31					sand (fluvial)	GdTL-3141	20900±1200	OSL	
32		no data	no data	no data	sand (fluvial)	GdTL-3142	13600±540	OSL	
33					sand (fluvial)	GdTL-3137	19800±1300	OSL	

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No.	Site name / Sample name	Long E	Lat N	Alt. [m a.s.l.]	Dated material	Lab. Code	Luminescence age [BP]	Technique TL/OSL	References
34	Lutomiersk Koziówki	19.22	51.75	152.5	sand (fluvial)	KIE-603	22900 ± 3400	TL	Kittel P. 2012. Budowa i ewolucja doliny Neru w rejonie stanowiska Lutomiersk-Koziówki w świetle badań geoarcheologicznych. Acta Geographica Lodziensia 100:113-133. (in Polish, summary in English)
35					sand (fluvial)	KIE-601	23100 ± 3500	TL	
36					sand (fluvial)	KIE-604	23300 ± 3500	TL	
37	Restarzew Środkowy	no data	no data	no data	sand (fluvial)	PIG364	12400±2800	OSL	Bieńko K., Cieślak A., Wieczorek D., 2022. Objaśnienia do Szczegółowej mapy geologicznej Polski w skali 1:50 000, arkusz Zelów (699) (Explanations to the Detailed Geological Map of Poland in the scale 1:50,000, Zelów sheet (699)).(in Polish) NAG, PIG-PIB Warszawa (electronical version).
38	Dubie	no data	no data	no data	sand (fluvial)	PIG363	14600±2500	OSL	