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THE ENVIRONMENTAL CONTEXT OF EARLY NEOLITHIC CULTURAL TRANSFORMATION IN THE TARGOWISKO SETTLEMENT REGION (SOUTHERN POLAND)

ABSTRACT

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The aim of this article is to provide information on environmental changes in the Targowisko region in the Early Neolithic as a natural response to settlement and economic activity of the human population in that area. The discussion is based on lithological, geochemical, and palynological analyses, as well as the analysis of Cladocera within strata inside the TRG (Targowisko) core, located in a small wetland in the immediate vicinity of the eastern edge of the Neolithic settlement in the Targowisko region. Settlement analysis points to the absence of stable microregions and to the mobility of human groups. This is confirmed by the sequence of settlement episodes and economic activity, reflected in the stratigraphy of the core sediments, where episodes of significant human interference are followed by phases of almost complete regeneration of the environment. No differences have been noticed between the *Linienbandkeramik* and Malice culture communities as regards their impact on the environment.

Key words: environmental conditions, Early Neolithic, LBK culture, Malice culture, Targowisko region, biogenic sediments, multi-proxy environmental reconstruction
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INTRODUCTION

The Targowisko settelment region is a unique archeological area, where numerous remnants of Early Neolithic cultural activity have been found (Czerniak 2013; Czekaj-Zastawny 2014; Grabowska and Zastawny 2014; Zastawny and Grabowska 2014a, b; Kadrow *et al.* 2020). The settlement of the eastern Targowisko region in the *Linienband-keramik* (hereafter: LBK) and Malice culture (hereafter: MC) periods (5300-4500 BC) did not form a typical, stable microregion with one central founding settlement (*e.g.* Pyzel 2019), inhabited continuously throughout the LBK or even until the end of the MC classic phase (*e.g.* site 16 in Rzeszów; see Kadrow 2020a). The examined material points to the relative instability of the microregions, the increased mobility of small human groups, and to risky decisions about settlement (Kadrow *et al.* 2021), noted also in many recently analysed regions, *e.g.* on the upper Danube (*e.g.* Pechtl 2020).

The environmental changes resulting from settlement and economic activity have already been investigated (Kalicki, 2014). However, due to the properties of the biogenic material, it was not possible to conduct a palynological investigation for the material falling within the timespan of the LBK and MC in this region. As it has been widely acknowledged that reconstruction of the environmental context is a very important part of archeological studies, we aimed to find new biogenic material that sedimented in water bodies or swamps, and that would be more suitable for environmental analysis. During the detailed geomorphological investigation, several swamps were recognized in the region, but only a few layers of strongly decomposed biogenic sediments were found, which turned out not to be suitable for palaeoecological analysis. Therefore, material was taken from the swamp that was previously investigated (Kalicki 2014). In the collected sediment core, the lithology was described and several analyses were performed: geochemical and palynological, as well as an analysis of subfossil Cladocera.

The main aim of the study was to provide information on environmental changes in the Targowisko region in the Early Neolithic as a response to settlement and economic activity of the human population in that area.

Geochemical composition of the sediment is more and more often used in the reconstruction of palaeoenvironmental conditions (*e.g.* Wojciechowski 2000; Borówka 2007,

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Ratajczak-Szczerba *et al.* 2014, Pleskot *et al.* 2018; Kittel *et al.* 2020). The assumption of these interpretations is that the main chemical components of biogenic sediments derive from different sources and that they accumulate in deposits in different physical-chemical conditions. In order to recognize the extent of denudation, whether generated by natural factors or induced by human activity – and especially relative changes in these types of processes – elemental contents can be used (Fe, Mn, K, Mg), as well as the sums of these elements relative to a normalisation element such as Ca. Paleoenvironmental conditions responsible for the sedimentation of the biogenic material were interpreted by determining the quantitative ratios of the elements and by classifying the deposits geochemically (Borówka 2007).

Pollen analysis is widely used in archeological studies to reconstruct not only general vegetation history, but past human impact on vegetation and past cultural landscapes as well (Gaillard 2007). This allows for the estimation of changes in vegetation under the influence of human activities, and provides some indication of the type of agriculture in the study area (Behre 1981, Gaillard 2007). Palynological studies contribute important data to environmental reconstructions and cultural and economic practices. The low representation of pollen and the high degree of sporomorph damage, which are characteristic of the so-called dry sites and old glacial areas, could significantly affect the interpretive capabilities and limitations of the method. However, even in this case, palynological data can provide useful qualitative data.

Subfossil Cladocera analysis is often used in paleolimnology in order to reconstruct environmental conditions in the past (Korhola and Rautio 2001). Cladocera are an important zooplankton component of freshwater lacustrine environments. Their remains, preserved in the sediment, clearly indicate the presence of a body of water – even a shallow one. Cladocerans are very sensitive to water depth (Nevalainen *et al.* 2011), temperature (Lotter *et al.* 1997; Zawiska *et al.* 2015) and pH changes (Locke and Sprules 2000; Zawiska *et al.* 2013). For this reason, they are useful in archaeology, because they help trace environmental changes resulting from human activity.

This article reports the results of environmental analyses as part of the project “Great culture transformation in microregional perspective. Trends of changes inside Danubian farmers an interdisciplinary study”. Other aspects of the investigations carried out within the project are presented in two articles published in this volume (Kadrow *et al.* 2021; Rauba-Bukowska 2021). When combined with data concerning material culture, technology and economy (see Kadrow *et al.* 2021; Rauba-Bukowska 2021), the information may contribute to resolving the question of whether the cultural transformation resulted from internal changes in the local Early Neolithic communities (*e.g.* Kadrow 2020a) or from the disappearance of the local LBK population and the arrival of new settlers from beyond the Carpathians, who developed the MC (*e.g.* Kozłowski *et al.* 2014). Considerations about the mechanisms of transformation, taking into account the results of environmental – nalyses, are contained in one of the two related articles (Kadrow *et al.* 2021).

THE LOCATION

The Targowisko settlement region lies in the borderland between the Carpathian Foothills (Wieliczka and Bochnia Foothills) and the Sandomierz Basin (Kondracki 2002; *e.g.* Kadrow *et al.* 2021, fig. 1), mostly in the valley of the Tusznica river, which flows into the Raba river, a tributary of the Vistula. The western part of this settlement region lies in the Podłężanka river basin, also a tributary of the Vistula. The area was glaciated during the

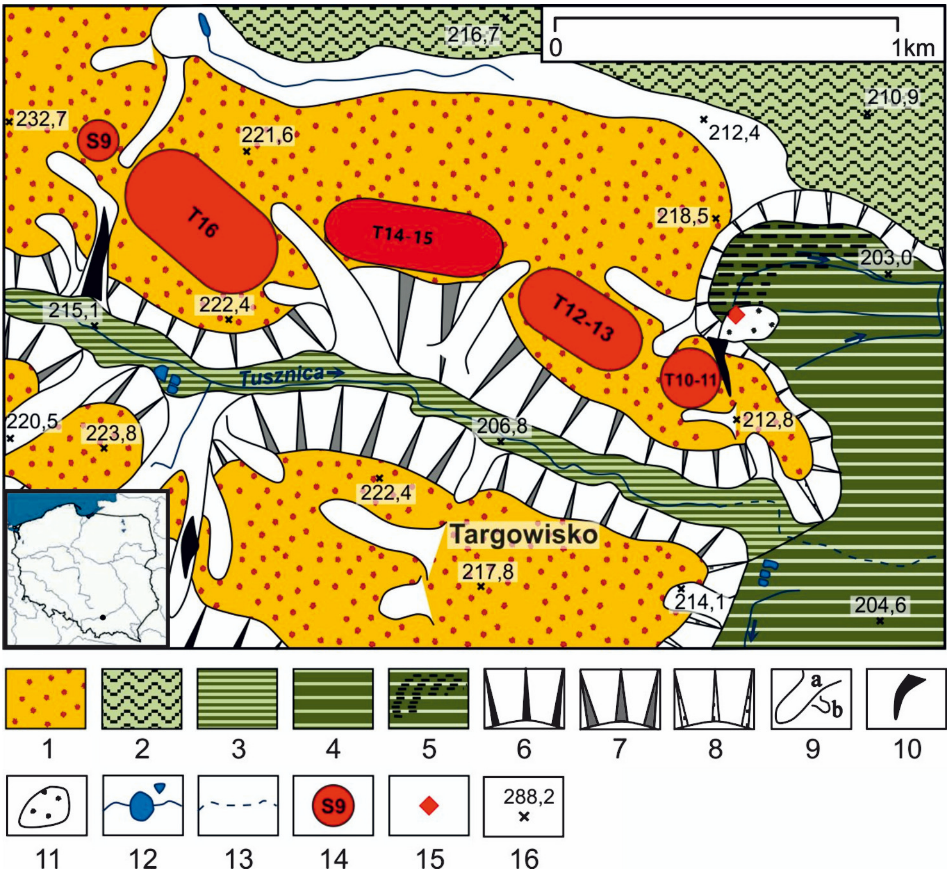

Fig. 1. Geomorphological map with the locations of the studied sites; 1 – morainic upland, denudated with loess mantle, 2 – alluvial plain (fluvial terrace), 3 – Tusznica River valley floor, 4 – high terrace (Raba river valley), 5 – mire (in paleochannel), 6 – slopes of foothill ridges, 7 – slopes of Tusznica River valley, 8 – slopes of Raba River valley, 9 – denudational dry valleys (a) and trough (b), 10 – gullies and other erosional cuttings, 11 – deluvial fan, 12 – river channels and artificial reservoirs, 13 – sewered and underground river channel, 14 – early Neolithic settlements (T10-11 – Targowisko site 10-11; T12-13 – Targowisko site 12-13; T14-15 – Targowisko site 14-15; T16 – Targowisko site 16; S9 – Szarów site 9), 15 – location of TRG core, 16 – hight-point m a.s.l.

Southern Polish (Elsterian) Glaciations (Mojski 2005), but its tills and glaciofluvial sand with gravel are covered by a loess mantle, approx. 10 m thick, accumulated during the Saalian and Vistulian cold stages (Maruszczak 1980).

The borderland between the Sandomierz Basin and the Wieliczka and Bochnia Foothills is poor in biogenic sediment, which could be used to track environmental changes in that area. Although several wetlands have been selected and identified there, biogenic sediments deposited in them have survived only as thin layers of highly decomposed material, with very limited usefulness for palaeoecological analysis.

The studied archaeological sites in Targowisko are located within near-valley strips of morainic upland covered by loess, or on slope flatness descending towards the bottom of the Tusznica river valley (Fig. 1). Biogenic sediments for palaeoenvironmental analyzes were collected from the wetland located directly north of the site of Targowisko 10-11. The wetland takes up a part of the Raba paleochannel shaped during the Late Vistulian (Kalicki 2014; 2015), bordered by a steepish slope more than 10 m high to the west, and by a flat alluvial plain to the east. The south-western part of the paleochannel is covered with a diluvial fan (Fig. 1). It formed during the Neoholocene, when mineral matter from the denuded slope and the surrounding upland was deposited there through a small gully (Fig. 1).

After identifying the thickness of organic sediments in the paleochannel and the diluvial series of the fan, a profile was selected for detailed palaeoecological examination. The profile, marked as TRG, was located in the western part of the fan (Fig. 1; φ = 49°59'17,7" N; λ = 20°17'54,7"E), approx. 30 m to the northwest of the TP3 core examined by Kalicki (2014). The earlier palaeogeographical and palynological analyses carried out in that place traced the development of that area from the Late Glacial to the historical periods. However, because the deposits analysed by Kalicki (2014) representing a significant part of the Atlantic period (synchronous with the Early Neolithic settlements) contained no pollen and showed discontinuities in sedimentation, the decision was made to resume exploration of the wetland.

MATERIALS AND RESEARCH METHODS

The TRG core was collected with a 50-cm-long Instorf sampler with double coring separated by 50 cm. Three general layers were documented within the core profile: 0-150 cm: a silt layer – mineral deposit with organic debris and peaty interbeddings (diluvial fan series); 150-510 cm: gyttja series (lacustrine deposits) – carbonate-detritus or carbonate-mud gyttja (Fig. 2); 510-550 cm: sandy series.

Detailed tests covered the material collected from a depth of 160-360 cm. Basic physical and chemical parameters, including organic matter content (LOI – loss on ignition), calcium carbonate content ($CaCO_3$), reactivity (pH) and conductivity of matter (Fig. 2), were measured for 64 samples in a 3-cm resolution, according to the procedure by Bengtsson

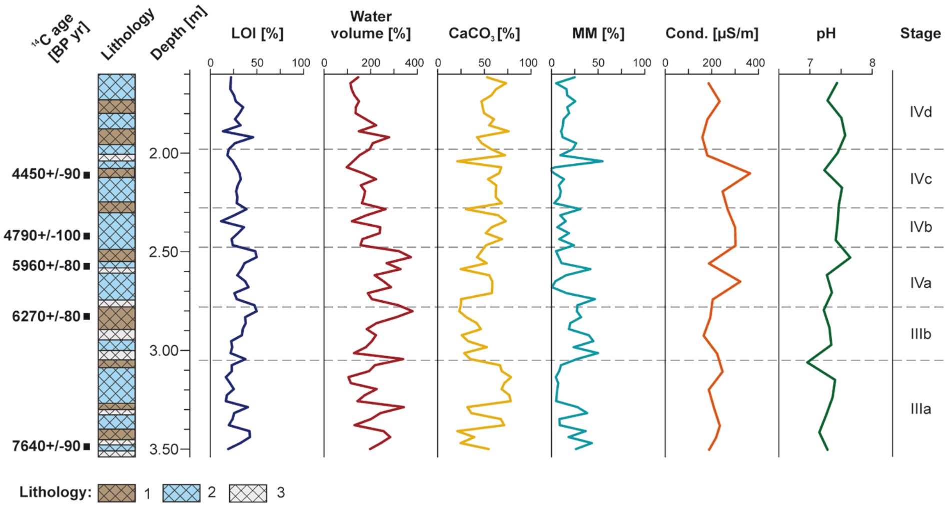

Fig. 2. Targowisko TRG-core. Basic physico-chemical parameters. Lithology: 1 – detrital-calcareous gyttja, 2 – calcareous-silty gyttja, 3 – clay gyttja

and Enell (1986). The calcium carbonate content was calculated by the Scheibler method, the reaction (pH) and conductivity were estimated by the conductimetry method, and the loss on ignition was obtained at 550°C (Myślińska 2010). Ash with no organic matter was dissolved with concentrated HNO_3, 10% HCl and H_2O_2 in a Berghof Speedwave microwave mineralizer. Elements with palaeogeographical significance (Na, K, Ca, Mg, Fe, Mn, Cu and Zn) identified in the resulting solution were marked by the atomic absorption spectroscopy method (AAS Solar Unicam).

Statistical analysis of the chemical composition included several indicators of the type and relative intensity of denudation processes (LOI/$CaCO_3$, Na/K, Ca/Mg, Na+K+Mg/Ca) (Fig. 3), as well as water table changes (Fe/Mn, Cu/Zn, Fe/Ca), with the use of Triplot and PAST (Hammer *et al.* 2001). After the solution was made in accordance with Clift *et al.* (2019), the grain size composition of the samples was determined with a Mastersizer 3000 laser particle size analyser (Malvern).

Five samples of the TRG core were radiocarbon dated (Table 1; Fig. 4) by the conventional method with the scintillation technique. This test was performed on the samples with approx. 2-cm-long intervals.

The palynological analysis covered sediment collected from a depth of 190-300 cm, from which 31 samples, each with a volume of 1 cm³, were submitted for standard laboratory processing. In order to prepare the material for microscopic analysis, the samples were treated with 10% HCl, 10% KOH, 40% HF and Erdtman acetolysis (Berglund and Ralska-Jasiewiczowa 1986). First, *Lycopodium* spores were added to each sample as an

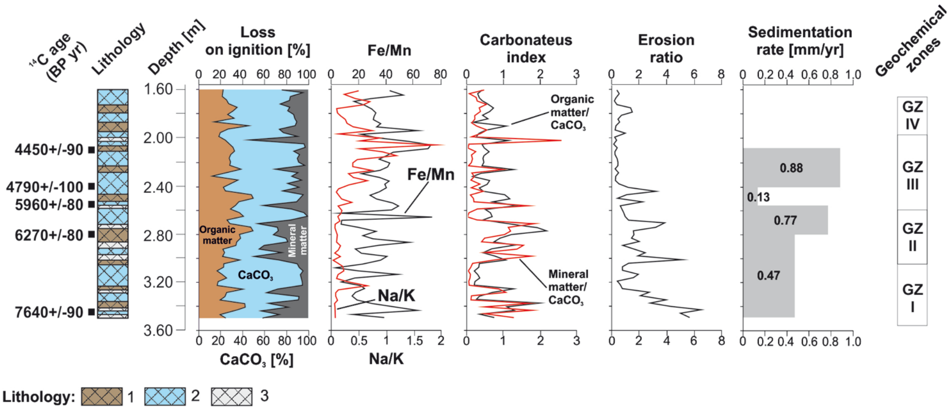

Fig. 3. Targowisko TRG-core. Variability of the conditions of sedimentation in the TRG profile, estimated on the basis of the geochemical ratios (Fe/Mn, Na/K, LOI/CaCO3, MM/CaCO3, catchment erosion) against the lithology, content of the basis lithogeochemical components and sedimentation rate. Lithology: 1 – detrital-calcareous gyttja, 2 – calcareous-silty gyttja, 3 – clay gyttja.

indicator (Stockmarr 1971) to calculate the absolute concentration of sporomorphs. Pollen and spore identification was based on the pollen key by Beug (2004) and the Northwest European Pollen Flora I-VIII (Punt *et al.* 2003). Depending on the quality of the sample, not less than 200 (from 215 to 498) pollen grains of trees, shrubs and terrestrial herbaceous plants (excluding Cyperaceae) were counted each time (AP + NAP-Cyperaceae = 100%; AP – Arboreal Pollen, NAP – Non Arboreal Pollen). Cyperaceae were excluded from

Table 1. Results of radiocarbon dating of the deposits from the TRG core (calibration after Calib Rev 8.1.0)

Depth of sample cm	Lab code	BP	BC - One Sigma Ranges	BC - Two Sigma Ranges
210	MKL-4489	4450±90	**[3334 - 3213] 0,421675** [3191 - 3147] 0,144471 **[3140 - 3012] 0,433854**	**[3360 - 2912] 1,000000**
240	MKL-4490	4790±100	**[3649 - 3500] 0,793679** [3433 - 3379] 0,206321	**[3778 - 3363] 1,000000**
255-257	MKL-4183	5960±80	**[4940 - 4776] 0,862974** [4759 - 4726] 0,137026	[5198 - 5189] 0,004598 **[5049 - 4672] 0,985704** [4662 - 4660] 0,000816 [4635 - 4617] 0,008882
280	MKL-4491	6270±80	**[5322 - 5206] 0,668432** [5170 - 5114] 0,223516 [5103 - 5073] 0,108052	[5467 - 5446] 0,016685 **[5380 - 5008] 0,983315**
344-346	MKL-4184	7640±90	[6587 - 6579] 0,046197 **[6574 - 6426] 0,953803**	**[6650 - 6353] 0,959546** [6312 - 6259] 0,040454

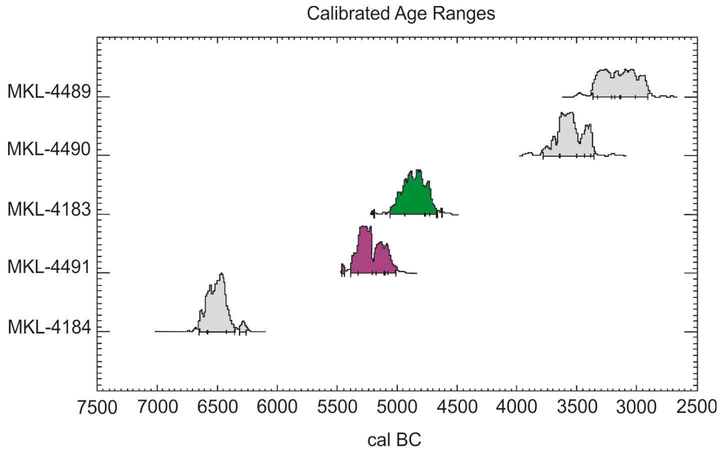

Fig. 4. Targowisko TRG-core. Radiocarbon dating of selected deposits from different core depths; the purple color of the probability distribution – existence of a settlement from the older phase of LBK; the green color of the probability distribution – existence of a settlement from the older phase of MC at site 11 in Targowisko (calibration after Calib Rev 8.1.0)

the basesum due to their typically local presence in the peatland, and their percentage was calculated in the same way as that of aquatic and spore plants. Finally, for palynological interpretation, 31 samples were used and 70 taxa were determined. The system of basic pollen curves and the CONISS analysis from the PolPal program package (Walanus and Nalepka 1999) made it possible to separate one pollen zone (TRG -1 L PAZ; L PAZ – Local Pollen Assemblage Zones) containing four sub-zones (TRG -1a – TRG -1d L PASZ – Local Pollen Assemblage SubZones). The selected curves of pollen taxa indicated the main environmental changes, and the beginning of agricultural activities were chosen for the diagram (Fig. 5).

Samples for the analysis of Cladocera (Crustacea: Branchiopoda) remains were likewise collected from a depth of 190-300 cm, but only some of them have been examined thus far. One cubic centimeter taken from each fresh sample was subjected to the standard laboratory procedure described by Frey (1986). Microscope slides were prepared from 0.1 ml of each sample and examined under a light microscope with magnifications of x100, x200 and x400. For each sample, 2-4 slides were scanned, and all skeletal remains, including head shields, shells and postabdomens, were counted. The identification of the Cladocera remains was based on the identification key by Szeroczyńska and Sarmaja-Korjonen (2007). Stratigraphic diagrams presenting the percentage of each species (Fig. 6) were prepared with C2 freeware (Juggins 2007). Subfossil Cladocera analysis is often used in paleolimnology in order to reconstruct environmental conditions in the past (Korhola and Rautio 2001). Cladocerans are very sensitive to water depth (Nevalainen *et al.* 2011),

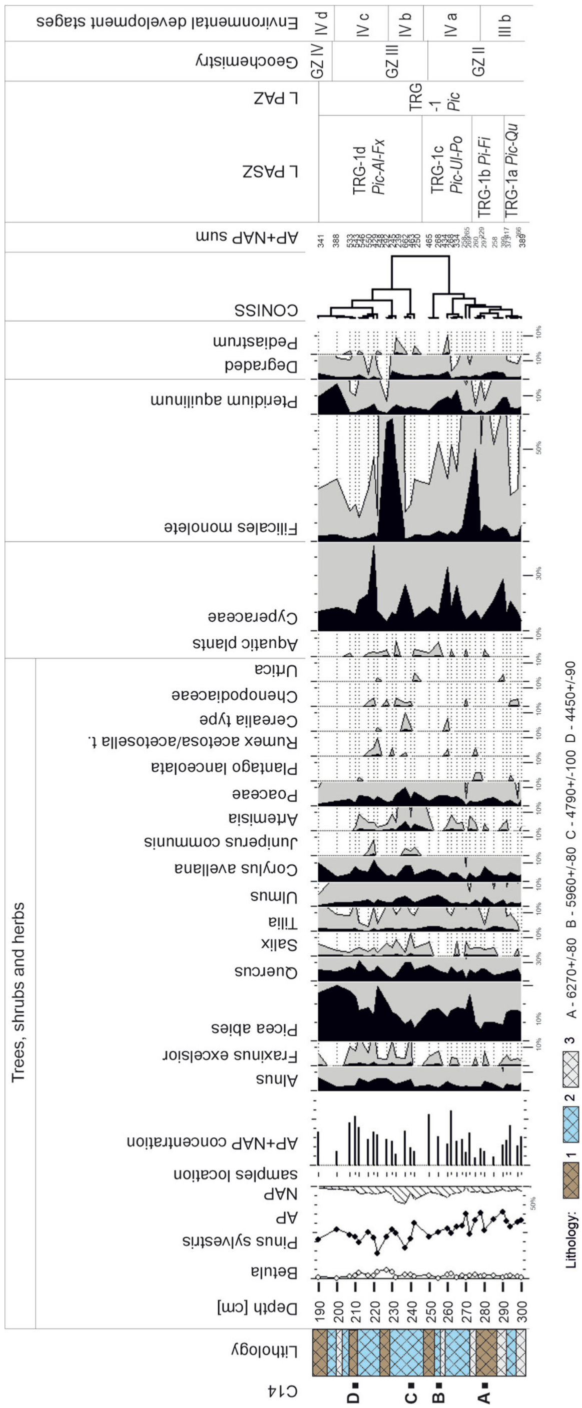

Fig. 5. Targowisko TRG-core. Percentage pollen diagram of the selected taxa

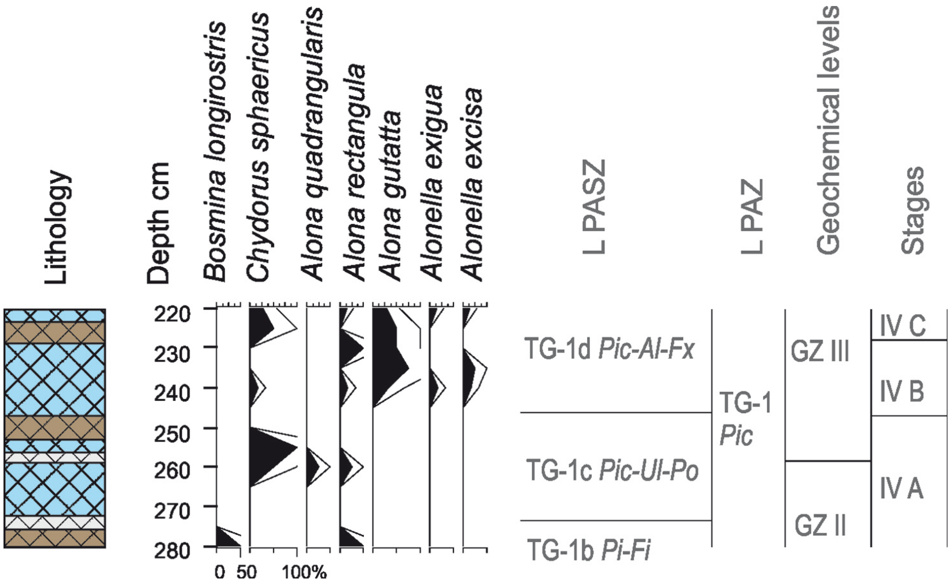

Fig. 6. Targowisko TRG-core. Percentage Cladocera diagram

temperature (Lotter *et al.* 1997; Zawiska *et al.* 2015) and pH changes (Locke and Sprules 2000; Zawiska *et al.* 2013). For this reason, they are useful in archaeology, because they help trace environmental changes resulting from human activity.

RESULTS OF PALAEOENVIRONMENTAL STUDY

The research covered the middle section of the TRG core, between a depth of 160 cm and 360 cm (Table 2), deposited during the Middle and Upper Holocene. The lower section of the paleochannel fill, accumulated during the Late Vistulian and the Early Holocene, does not reflect any human influence (Kalicki 2014). Radiocarbon dating allowed for the indication of the presumptive section of lake deposits that developed contemporaneously with the presence of the Neolithic communities in this area. They thus coincided in time with the research project mentioned in the introduction. Therefore, palynological and Cladocera analyses were performed for the section between 190 cm and 300 cm (Table 2). The identified parameters of the sediments from the TRG core are described below in the chronological order of their accumulation.

The analysed sediments were described as lake deposits – gyttjas, with a high content of calcium carbonate and a variable content of mineral and organic material, allowing for the determination of the type of sediment (Stasiak 1971; Markowski 1980). They were deposited in a shallow reservoir, probably periodically, even with a disappearing water surface. However, the lack of peat inserts in the sediments excludes the pool being occupied by peatland. The mineral matter in the gyttja may come from denudation of the surrounding slopes that washed into the reservoir, and from microelements in the composition of organisms. Its increasing share in the Holocene deposits is interpreted as an effect of the unnatural exposure of the terrain surface and its exposure to denudation (Tobolski 2000, Myślińska 2010).

The chemical composition of analysed deposits allows for the calculation of some indicators: the type of denudation indicator Na/K, the erosion index of the catchment area

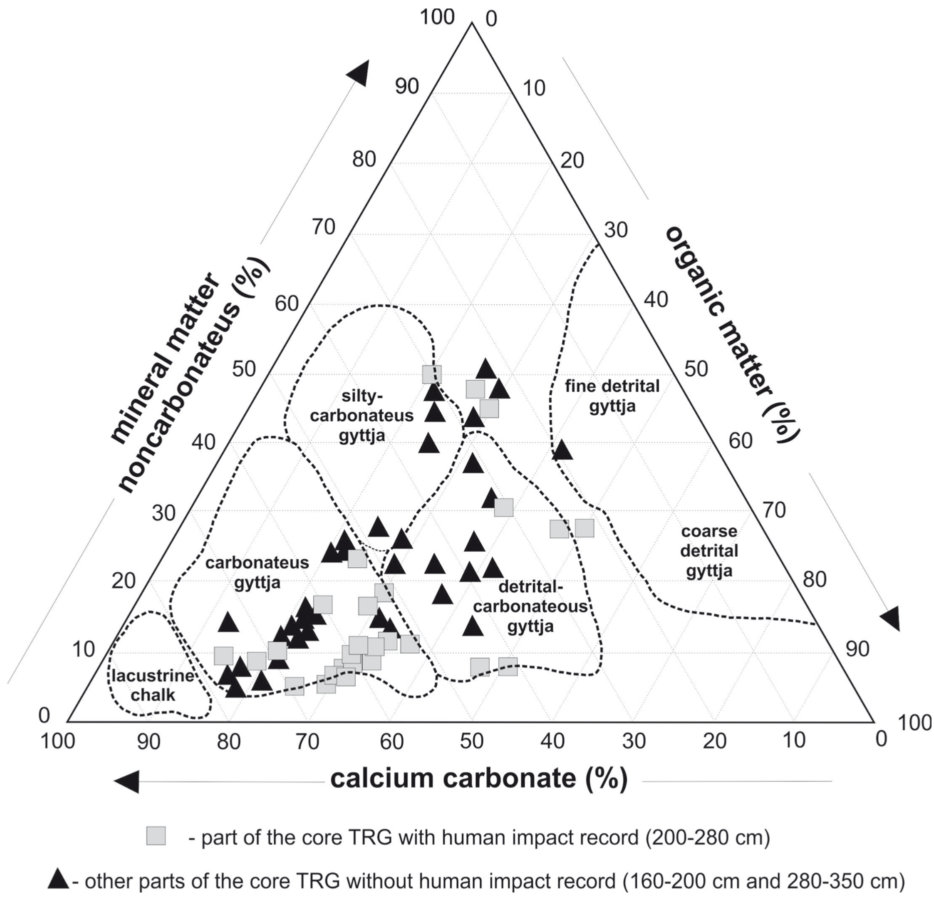

Fig. 7. Targowisko TRG-core. Relationship between the content of lithogeochemical elements in the sediments of the TRG profile against the classification type of biogenic deposits (after Markowski 1980)

Table 2. Selected results of TRG core analyses in stratigraphic order

Sedimentary stages	Geochemistry	Pollen	Cladocera
Calcareous-silty gyttja (160-216 cm); High content of calcium carbonate (to 75%), two specific episodes: low content of mineral matter - 2,6% (209-212 cm), and its rapid increase to 54% in 203 cm; 211-210 cm dated to 4450±90 BP (Table 1; Fig. 4).	**GZ IV (160-198 cm);** distinct changes in the ratio of redox conditions: an increase in Fe/Mn and a decrease in Ce/Fe, in the ratios of the type denudation processes: a decrease in Na/K. **GZ III (198-250 cm);** In top part (up 216 cm) increase in Fe/Mn and Ce/Fe are observed, an erosion ratio is low.	**TRG-1 *Picea* (190-300 cm);** High *Picea* (7-27%; av. 14%) with tends to rise. Relatively high participation of *Pinus* with a gradual decline (from 60 to 30%). All other trees oscillating. Numerical analysis (CONISS) suggests the similarity and confirms this division to one LPAZ and three L PASZ.	**TRG-1** Seven Cladocera species were found: *Bosmina longirostris, Alona rectangula, Alona quadrangularis*, *Chydorus sphaericus, Alonella excisa*, *Alonella exigua* and *Alona guttata*.
Calcareous-detrital gyttja (216-228 cm); A relatively high content of $CaCO_3$ (about 60%), and a stable content of organic matter. **Calcareous gyttja (228-248 cm);** high content of $CaCO_3$ and several fluctuations in the mineral matter, content of organic matter also oscillates but increase to top; 240-239 cm dated to 4790±100 BP, (Table 1; Fig. 4).	In lower part the erosion index of the catchment area decreases from 3.2 to 0.2, while the Fe/Mn index remains stable (21-42), and chemical denudation processes intensify (the Na/K ratio increases from 0.07 to 0.74).	**TRG-1d *Picea-Alnus-Fraxinus* (190-250 cm);** Gradual increase of *Picea* (7-26%). Relatively high and variable participation of *Quercus*, *Corylus* and *Alnus*. Higher frequency of NAP at the beginning of the phase (mainly *Artemisia*, Brassicaceae, Poaceae and *Rumex*). Frequency and variety of anthropogenic indicators grows. Variable frequency of Cyperaceae (7-46%) and Filicales monolete (1-64%). Aquatic plants and Pediastrum appeared. Changeable concentration of sporomorphs.	**TRG-1d** 5 Cladocera species were found, those living among the plants dominated *Alona guttata (50%), Alonella excisa and Alonella exigua.* At depth 245-250 cm no remains were found.
Detrital-calcareous gyttja (248-284 cm); The content of organic matter in relatively high there, its average value being the highest in the entire profile. The content of mineral matter decreases sharply from the depth of 272 cm	**GZ II (250-305 cm);** Two clear peaks of an erosion ratio (275-278 cm and 300 cm); Rapid changes of the Fe/Mn index between 260 and 275 cm, but at a stable level of Na/K index. In lower part the variability of Fe/Mn index is less intense,	**TRG-1c *Picea-Ulmus*-Poacea (250-275 cm).** The upper limit: Decrease of *Picea* and increase of NAP; High frequency of *Picea* (50-67%) and *Pinus* (8-23%, av. 14%) and rising *Ulmus* (form1 to 5,5%) and *Corylus* (from 1 to 5%). Higher frequency of NAP (mainly Poaceae, *Artemisia*, Brassicaceae). Single pollen grains of Cerealia appeared. High participations of	**TRG-1c** Three species were uncontinously present *Chydorus sphaericus, Alona quadrangularis*, and *Alona rectangula.*

upwards, while $CaCO_3$ increases rapidly; at the depth of 266 cm, the content of mineral matter does not reach 1% and the content of organic matter is high. 281-280 cm dated to 6270±80 BP (Table 1; Fig. 4).	likewise the erosion ratio. The carbonaceous ratio is between 0,5 and 1,5; the values of the grain-size ratio, especially GS11, rise gradually from 1.66 to 3.26.	Cyperaceae and *Pteridium aquilinum*. Lower values of degraded sporomorphs. Aquatic plants and Pediastrum appeared. Relatively high concentration of sporomorphs.	
Calcareous-silty gyttja (284-326 cm); The percentage of $CaCO_3$ and mineral matter is more characteristic there: in samples taken from the lower part, $CaCO_3$ quite consistently has the frequency of up to 80%, while the content of mineral matter is very low.		**TRG-1b *Picea*-Filicales (275-290 cm)**. The upper limit: increase of *Picea* and decrease of Filicales; High frequency of *Pinus* (50-67%) and lower *Picea* (5-9%). The other of mesophilous trees still in lower, more or less the same as earlier, participations. Filicales monolete frequency is rising (from 5 to 47%) but *Pteridium aquilinum* decreasing (7-0.7%). NAP still low. Single pollen grains of *Artemisia* and *Urtica* appeared. Higher values of degraded sporomorphs. Relatively low concentration of sporomorphs. Numerical analysis (CONISS) confirms joining the spectra into one L PASZ. **TRG-1a *Picea-Quercus* (290-300 cm)**. The upper limit: decrease of *Picea* and *Quercus*; High frequency of *Picea* (14-15%), *Pinus* (50-60%) and *Quercus* (3-6%). Lower participation the other of mesophilous trees: *Alnus*, *Fraxinus*, *Tilia*, *Ulmus* and *Corylus*. Poaceae, Filicales monoete and *Pteridium aqulinum* are continuously present. Cyperaaceae frequency is rising. Degraded sporomorphs are at lower values. Relatively high concentration of sporomorphs.	**TRG-1b** Two Cladocera species present at depth 280 cm, *Bosmina longirostris* and *Alona rectangula.*
Detrital-calcareous gyttja (326-360 cm); Varying content of $CaCO_3$ (Fig. 2) and of organic matter (20%-45%) Mineral matter is mostly very coarse or coarse in structure, with a slight admixture of sand and clay. 346–344 cm dated to 7640±90 BP (Table 1; Fig. 4).	**GZ I (305-360 cm);** This section shows low values of oxidizing conditions (the Fe/Mn ratio below 40) and low values of the type of denudation indicator Na/K (0.06 on the average).		

(showing the size and type of denudation) and values of oxidizing conditions (the Fe/Mn), the carbonaceous ratio, coefficient of the Fe/Mn with other geochemical ratios, and redox (showing the chemical state in the reservoir). The values of the analyzed parameters and indicators are shown in the table and figures (Table 2, Fig. 2; 3; 6).

Palynological analyses of the deposit from the Targowisko mire made it possible to describe the changes in the natural environment, but only to a limited extent. The examined sediment formed in a reservoir with an unstable groundwater level, which had a decisive impact on the condition of sporomorphs. Periodic desiccation, recorded both in the structure and the physical and chemical analysis of the material, was detrimental to the preservation of pollen. The palynological results and the radiocarbon dating show that the analysed section of the profile records plant succession from the mid-Atlantic to the beginning of the Subboreal period. Pollen records show that in the general scheme of vegetation development in the TRG, the profile has a very similar character to the other described sites from the vicinity (Wasylikowa *et al.* 1985; Kalicki 2014). During the analysed period, the area surrounding the Targowisko sites was overgrown by forests. They were dominated by pine (*Pinus sylvestris*) and spruce (*Picea abies*), with an admixture of oak (*Quercus*), elm (*Ulmus*), lime (*Tilia*), ash (*Fraxinus*) and hazel (*Corylus*). Wetlands in the Tusznica river valley were covered by alder (*Alnus*) and riparian forest, as is evidenced by the presence of alder but also elm and ash. An important issue is the high participation of spruce in the diagram (7-27%). This could indicate that it was an important component in the forests of that time. Although it is a wind-pollinating species, its relatively large and heavy pollen grains are not carried by the wind over long distances (Obidowicz *et al.* 2004). From contemporary analogies, it appears that as little as a 5% participation of spruce in the diagram may indicate regional expansion of this species (Obidowicz *et al.* 2004). Comparing this with the data summarized in the isopolen maps (Obidowicz *et al.* 2004), we can observe a higher proportion of it in the corresponding periods. A similar situation was noted in the TG profile (Kalicki 2014). This may indicate that it was locally more widespread in the forest communities in the Targowisko region. However, it should not be forgotten that spruce pollen grains are relatively easy to recognize even when the material is severely damaged, and their higher occurrence may be over-represented. Throughout the analysed period, the presence of open areas that could bear traces of human activity was relatively small. The NAP curve ranges from 5% to 15% (Fig. 5), and the dominant plants were grasses (Poaceae), which, like sedges (Cyperaceae), may largely have come from wetlands and peatbogs in the valley. The high and fluctuating proportion of grasses, sedges and ferns (Filicales monolete) suggests an unstable groundwater level resulting in the alternate flooding and drying out of the peat bog. Brief descriptions of local pollen zones and subzones and their basis of delimitation are presented in Table 2.

Cladocera are an important zooplankton component of freshwater lacustrine environments. Their remains preserved in the sediment clearly indicate the presence of a body of water – even a shallow one. Individual Cladocera species differ in their ecological requirements; therefore, Cladocera assemblages provide valuable information about the water habitat in the past. Analysis of the species composition for the Targowisko region has been carried out on the middle section of the TRG core (depth of 280-220 cm) with a resolution of 5 cm (Fig. 2). The results are presented within the palynological subzones (Table 2).

INTERPRETATION AND DISCUSSION

The features and thickness of mineral and organic deposits accumulated in basins of the reservoir depend on the environmental conditions in the surrounding area. Those changes, as well as human activity, have an influence on the type of sediments (Tobolski 2000). The results of lithological, geochemical and palinological analyses supplemented by the radiocarbon dating have served as the basis for a preliminary reconstruction of environmental conditions recorded within the paleochannel in Targowisko. The compilation of the TRG core analysis results made it possible to distinguish the environmental development stages. The first and second stages are not presented in this work, as they fall in the Late Glacial and Early Holocene, when no human activity was recorded in the study area. The description begins with stage IIIa, correlated with the Middle Holocene.

However, there are several factors that complicate the tracking of the environmental changes. The results of the analysis of the lithology and geochemistry of sediments, as well as of Cladocera, indicate changes taking place in the immediate vicinity of the reservoir, in the area from which water flows with soil material. The examined area had a fluctuating water level, and the basin was periodically without surface water. Comparison of the preliminary results of the Cladocera analysis with the geochemical data shows that the Cladocera remains were present in sediments with a large content of organic matter (approx. 50%) and absent from sediments with a high content of $CaCO_3$ (approx. 70%). This may suggest that only the organic sediments are of a lacustrine origin in the studied site. The pollen analysis records changes in both the local and regional environment (Nalepka 1994; Tobolski 2000), which is beyond the Tusznica catchment in the study site. As a result, it cannot be ruled out that the environmental changes in nearby sites (such as Targowisko 12-13, 14-15 and 16), situated 200-1500 m to the west of the TRG core (Fig. 1), are also reflected in the pollen spectra of the studied core. Therefore, the palynological record of human influence is not synonymous with lithological and geochemical indications of enhanced human activity in the immediate vicinity of the TRG, *i.e.* mainly at site 10-11 in Targowisko (Fig. 5). Filicales and Cyperaceae show a clear dependence on habitat conditions in the Targowisko catchment. Fluctuations of the Filicales curve show a negative correlation with the curve of the sum of Cyperaceae and Cladocera. This would support the earlier thesis that, as a result of lowering water levels, the basin is being drained and wetland plants and aquatic organisms are disappearing, and vegetation, including ferns, is invading the mire. However, if ^{14}C dates are correct, the palynological diagram presents the entire sequence of Early Neolithic settlement phases from LBK I to MC Ib, already reported from this region (Kadrow *et al.* 2021).

The comprehensive field study in the Targowisko region previously conducted by Zastawny (Zastawny 2014) made it possible to correlate the sequence of settlement phases distinguished in the above-mentioned publication with the sequence of environmental changes recorded in the studied core (Kadrow *et al.* 2021). The situation is further complicated by the fact that, according to the recently published new ^{14}C date series (Czekaj-Zastawny *et al.* 2020; Kadrow *et al.* 2021) and stylistic analyses (*e.g.* Kadrow 2020b), the chronological phases may have overlapped one another on the regional scale.

Stage IIIa (360-305 cm), according to the radiocarbon dating, can be correlated with the Middle Holocene (Table 1; Fig. 4, 5). Detrital-calcareous gyttja with a significant content of $CaCO_3$ resulting from a supply of dissolved carbonate was deposited in the lower part of that section (IIIa) by migrating groundwater (Fig. 3). This origin of the water in the lake is confirmed by the high (slightly alkaline) pH of the sediments. The contents of organic matter and mineral matter exceed the content of $CaCO_3$ in two episodes, which may indicate a low water level (Wojciechowski 2000; Ratajczak-Szczerba *et al.* 2014). The analysis of grain size shows the dominance of silty fractions and low variability, possibly linked to the moderate accessibility and proximity to the sources of the material subjected to denudation. The dating of the gyttja sample from a depth of 346-344 cm (Table 1; Fig. 4) suggests that this section should be correlated with the Atlantic period of the Holocene (Starkel *et al.* 2013). The examined samples of stage IIIa bear no traces of human activity influencing the environmental disturbances, although the region seems to have been penetrated by a Mesolithic population at that time (Wilczyński 2014).

In **stage IIIb (305-278 cm)**, the content of $CaCO_3$ is very high and fairly stable at first, while the content of mineral matter is very low, which must have resulted from a very limited supply of silty material provided by mechanical denudation processes, as confirmed further by the changing Na/K ratio: a sharp decrease from 0.66 to 0.02. The section at a depth of 326-308 cm, therefore, corresponds probably to the period of stabilization in environmental conditions, rather without human interference. Conversely, the decrease in the content of mineral matter and in pH, along with the simultaneous increase in conductivity at a depth of 308 cm, seem to have been a response to a strong environmental impulse in the catchment area. The high content of mineral matter may have been caused by the thinning of vegetation on the slopes, which intensified mechanical denudation and the leaching of minerals from the soil cover, as evidenced by the increase in the erosion index from 0.42 to 5.2 (Fig. 3). The geochemical and lithological parameters at a depth of approx. 300-284 cm, vary in their values, with two distinct fluctuations. This suggests that the pressure on the habitat was not so much constant and homogenous as episodic, though periodically strong.

This stage includes two subzones distinguished in the pollen diagram (TRG 1a-1b L PAZ; Fig 5). The pollen results show scarce vestiges of human activity. There are single grains of ruderal plants: *Artemisia*, *Urtica* and Chenopodiaceae, and one sample containing pollen of *Plantago lanceolate*, a ribwort plantain typical of meadows (Behre 1981). This may point to animal husbandry in that period. However, the high percentage of *Pteridium aquilinum* – bracken fern characteristic of burnt-out places (Latałowa 2007) – may suggest that the area was penetrated by small groups of people. There are no traces of cultivation, but crops could have been grown in small forest clearings, in more favourable habitats or at a distance from the small lake in Targowisko. These plants are entomophilous or autogamous, and so produced a low quantity of pollen. And, the relatively high degree of afforestation could have prevented pollen migration from these places.The afforestation rate remains high – the forests being dominated by spruce (*Picea*), pine (*Pinus*) and oak (*Quercus*) and with an admixture of hazel (*Corylus*) in the lower layers. One should also note the high proportion of degraded grains (Fig. 5) and the apparently selective distribution of sporomorphs.

In stage IIIb, two Cladocera species, *Bosmina longirostris* and *Alona rectangula*, were present, which suggests the high trophic state of water (Whiteside 1970; Duigan 1992) at a depth of 280 cm. However, the poor species diversification may also suggest unfavourable environmental conditions such as the periodical drying of the reservoir. At a depth of 275 cm, no Cladocera remains were found, which further evidenced a lack of appropriate water conditions.

This section may correspond to the older (I) phase of the LBK, the Zofipole phase, the most intensive one in the entire settlement sequence identified at Site 10-11 in Targowisko. The archaeological finds from that phase include traces of eight longhouses built in two construction stages and forming a medium-sized settlement (Zastawny and Grabowska 2014a, 104-108, fig. 18, 41). At that time, agriculture consisted of the intensive cultivation of small forest clearings (Kruk and Milisauskas 1999, 44-46; Nowak 2009, 204-210), which is confirmed by research carried out in Targowisko and its vicinity (Nalepka 2015, 346-349).

The next stage – **IVa (278-248 cm)** – shows the varying environmental influence on the wetland. From a depth of 278 cm upwards, there is a noticeable increase in the mineral content after a short episode of stabilisation and perhaps regeneration of the surrounding area. The upper part of that section records a sharp drop in the mineral content to a mere 1% at a depth of 266 cm, as well as a significant increase in $CaCO_3$ and in organic matter (Fig. 2). For these reasons, the stratum seems to have been formed when denudation of the surrounding slopes stopped for a short time (as shown by the decrease in the Na+K+Mg/Ca ratio from 3.8 to 0.58 and by the stable Na/K ratio) and when vegetation cover developed in the catchment area and the wetland. These data point to the diminishing rate of denudation and possibly to the transformation of the reservoir into a periodic wetland, which would have made it difficult to supply material from the slopes to the centre of the mire.

This stage includes one subzone distinguished in the pollen diagram (TRG-1c L PAZ; Fig. 5). During the analysed stages, the surroundings of the Targowisko sites were overgrown by forests dominated by spruce (*Picea abies*) and pine (*Pinus sylvestris*). The record of human activity in this part of the sediment is still low. However, a greater presence of herbaceous plants (NAP curve in the graph), including taxa from the synanthropic plant group, may indicate human influence on the environment. The pollen diagram shows an almost continuous curve of *Artemisia* and occasionally *Rumex*. The single reappearance of *Plantago lanceolata* suggests that the surrounding area could still be used for grazing. The first crop indicators (cereals – type Cerealia) appeared in the diagram for the first time. The rapidly increasing percentage of ferns (Filicales monolete) at a depth of 275 cm may have resulted from a falling water level. Human activity could also be reflected in the fluctuating water level shown by the varying percentages of ferns and sedges. Deforestation of even small, mid-forest clearings may have disrupted water management in this small basin, but we cannot exclude that a hiatus appeared here.

However, in general, the pollen diagram shows that the impact of the human economy on the natural environment was still relatively small.

A sample taken from a depth of 257-255 cm has been radiocarbon dated to 5960±80 BP, which gives a calibrated timeframe of 4950-4800 BC (Table 1; Fig 4). Thus, the episode dated to *ca*. 5100 BC may have been related to the late (III) phase of the LBK, which has left no settlement traces at Site 10-11, but which has been recorded at sites located a little more to the west (Targowisko 12-13, 16; *cf*. Kadrow *et al*. 2021). These sites (12-13 and 16) also lie in the studied wetland catchment, and the effects of human impact could be recorded in the biogenic sediments, even if there was no settlement at site 10-11.

The remains of three Cladocera species – *Alona quadrangularis*, *Chydorus sphaericus* and *Alona rectangula* – documented at a depth of 260 cm, suggest that the reservoir was rather shallow during their accumulation (Fig. 6). Those taxa may also indicate the high water trophic status (Whiteside 1970), possibly caused by human activity nearby. This is accompanied by an increase in the mineral content up to 50% and a simultaneous increase in the concentration of all elements, particularly Zn and Cu. Conversely, the erosion index for the catchment area rises only slightly despite the increasing concentration of K, Na and Mg. These data may suggest that nutrients were delivered to the wetland due to fires, documented at many sites with a confirmed geochemical record of human activity (*e.g*. Pleskot *et al*. 2018; Kittel *et al*. 2020). The changes coincide with the transition from clay gyttja to calcareous gyttja. In the pollen diagram, plant species linked to human activity (*Artemisia*, *Rumex*, Cerealia, Chenopodiaceae) have been recorded at a depth of 260-275cm (Fig. 5).

The evidence of intensifying human activity might be related to the settlement consisting of four buildings at site 10-11 in Targowisko in the older (Ia) phase of the MC (Grabowska and Zastawny 2014, 255-261, fig. 1, 4-6). Since there were no major changes in the recorded environmental sources, it can be assumed that there were also no major changes in subsistence strategies as compared to the preceding LBK period (Kadrow 2020a, 101; Kadrow *et al*. 2021).

During stage **IVb (248-228 cm)**, calcareous-silty gyttja reappears in the core. Despite the varying content of $CaCO_3$ and of mineral matter, the lithological and geochemical composition remains stable. The poor geochemical record may have resulted from a decrease in the average rate of biogenic accumulation, and those two phenomena would point to low human activity.

This stage includes the older part of subzone TRG-1d, characterised by the strongest human impact on the natural environment. In the pollen diagram, the proportion and the variety of light-loving plants increase, and both the composition and the acreage of the forests change. The percentage of pine declines, while the percentage of trees with edible fruits rises, such *Quercus* and *Corylus* (Fig. 5). Acorns and hazelnuts could be used for both human and animal food. There were mixed forests nearby the Targowisko basin. At this time in the diagram, the proportion of herbaceous plants increases significantly, and the concentration of pollen decreases (Fig. 5). This may indicate an increase in the area of deforested land. From among herbaceous plants, species typical of wet meadows (*Plantago lanceolate*, *Rumex*), dry pastures (*Junipers*) and crops (Cerealia), but also of ruderal areas (*Artemisia*, *Rumex*, *Urtica*) are present, which suggests that the vicinity was used in various ways by humans. The general palynological pattern would indicate that settlements or small groups of people were some distance from the study reservoir. This stronger human impact resulted in greater changes to the landscape, which may have increased erosion. Afterwards, the groundwater level probably decreased allowing ferns to spread.

The Cladocera species identified at a depth of 240 cm are typically linked to the aquatic vegetation *Alonella excisa*, *Alonella exigua* and *Alona guttata* (Flössner 2000); no species characteristic of an open water zone has been recorded in that layer. The reservoir, therefore, must have been very shallow and overgrown with aquatic plants at that time (Duigan 1992; Zawiska *et al.* 2019). In the pollen spectra of that section (242 cm), single grains of *Sparganium*, *Comarum palustre* and algae from the Chlorophyta group (Pediastrum) appeared. At the same time, the proportion of sedges in the diagram increases, which may also indicate the wetland character of the described reservoir.

The excavated part of site 10-11 in Targowisko has yielded only modest vestiges of the Lublin-Volhynia culture (*cf.* Zastawny and Grabowska 2014b, 417-419, fig. 1, 2). The stronger human influence discernible in the pollen diagram, therefore, must have been related to a larger Lublin-Volhynia group inhabiting probably the northern part of the site, which has not been explored as yet. Ample traces of settlement from that period have been found at site 2 in Zagórze, over 8 km to the west of the TRG core (Kadrow *et al.* 2021, fig. 1). The inhabitants there belonged to the Lengyel culture (the Pleszów-Modlnica group; *cf.* Kadrow *et al.* 2020).

Stage **IVc (228-198 cm)** is connected with calcareous-detrital gyttja deposition, indicating a certain stabilisation in the supply of material to the basin. The proportion of mineral matter does not exceed 2%, which results from low physical denudation, while chemical denudation is more noticeable. This stratum presents the poorest geochemical record of human activity due to the diminished concentration of trace elements (Cu, Zn) and lithophilic elements (Fig. 3). This is also confirmed by the pollen analysis. The younger part of the pollen subzone TGR1-d is again characterised by an increase in the representation of trees and the pollen concentration in the sediment. The pollen diagram reflects the regeneration of forests on wet and dry locations. Among the trees, spruce shows the greatest increase in representation. The share of pine, oak and hazel is also relatively high, which testifies to the significant presence of these taxa in the forest stand at that time. Although, in the pollen diagram, some traces of human activity reappear after the decrease of the fern curve at a depth of 222 cm (Fig. 5). However, the extent of deforestation remains small in that part of the Neolithic, as noted in previous publications (Kalicki 2014).

Small human groups representing the Funnel Beaker culture or the Baden culture left modest traces in that period (Zastawny and Grabowska 2014b, 421, fig. 2).

Stage **IVd (198-160 cm)** occupies the upper part of the TRG profile, representing the final developmental phase of the basin, consistingof calcareous-silty gyttja. Two episodes can be identified within it on the basis of physiochemical parameters (Fig. 2), denoting an increase of denudation intensity in the reservoir catchment area.

Only one pollen sample is included in this stage. A higher proportion of alder and hazel is recorded; however, in the basin in Targowisko, spruce and pine still dominate the forest communities, with the participation of oak, elm linden and hazel.

This stage can be dated to younger than 2900 BC, and thus goes far beyond the age range of the analyzed problems of human activity.

CONCLUSIONS

Pollen results indicate that the surroundings of the study site were covered mainly by pine and spruce forests, with an admixture of deciduous forests with oak, elm, lime, ash and hazel.

However, in general, the pollen diagram shows that the impact of the human economy on the natural environment was still relatively small. On the basis of single occurrences of anthropogenic pollen indicators, periods of human activity can be described. Based on the palynological data, human activity was mainly pasture and to a lesser extent, the cultivation of cereal plants. Rapid changes of Cyperaceae and Filicales monolete indicate water level fluctuations and possible sediment hiatuses.

Preliminary Cladocera results indicate that biogenic sediments from the Targowisko site were of lacustrine origin in some periods, and therefore have potential for further Cladocera-based reconstructions. The results obtained so far suggest water-level fluctuation and lake productivity changes, which were probably due to human impact.

The lithological and chemical composition of the sections of the analysed core characterize subsequent periods of human influence on habitat conditions. The carbonate sediments of wetlands, with a modest amount of allochthonous elements, represent the Mesolithic (6500 BC), while sections consisting of carbonate gyttja, contemporaneous with phase I of the LBK (5300-5200 BC), bear distinct traces of chemical and mechanical denudation. Distinct changes took place in the catchment area of the marshland *ca*. 5100 BC.

Samples of biogenic core sediments dated to 4950-4800 BC show geochemical properties related to human activity, which indicates further changes in the environment, possibly caused by population from the older (Ia) phase of the MC.

The next section of the analysed core, dated to *ca*. 3700 BC, shows the relatively small impact of human activity on the chemical and lithological properties of the sediments. This marks the beginning of the Eneolithic, with the more intensive occupation of the Lengyel culture (Pleszów-Modlnica group) in the western outskirts of the region in Zagórze, site 2.

The analysis of the lake sediments of the studied core from Targowisko revealed changes in the characteristics of sediments and the composition of pollen and fossil remains of aquatic organisms, correlated with the phases of settlement and economic activity. It can be assumed that human activity influenced the habitat conditions in the reservoir, leaving a permanent record in its sediments.

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