Geological Quarterly, 2023, 67: 55
DOI: http://dx.doi.org/10.7306/gq.1732

This paper is a part of *Climate and environmental changes recorded in loess covers* (eds. Maria Łanczont, Przemysław Mroczek and Wojciech Granoszewski)

Prehistoric human influence on soil dynamics and slope transformation on the Subcarpathian Loess Plateau, southeastern Poland

Piotr GĘBICA[1, *]

[1] University of Rzeszów, Institute of Archaeology, Moniuszki 10, 35-015 Rzeszów, Poland; ORCID: 0000-0001-8109-267X

Gębica, P., 2023. Prehistoric human influence on soil dynamics and slope transformation on the Subcarpathian Loess Plateau, southeastern Poland. Geological Quarterly, 2023, 67: 55; http://dx.doi.org/10.7306/gq.1732

This study examines the impact of prehistoric human activities on the landscape of the Subcarpathian Loess Plateau, focusing on areas such as the Kańczuga Plateau in southeastern Poland. Through a multidisciplinary approach that integrates archaeological excavation, soil profile analysis, and geomorphological survey techniques, environmental changes are traced from the Neolithic through the early Middle Ages. A key aspect comprises various soil types, particularly chernozems and brown soils, which have been influenced by early agricultural practices like deforestation and land cultivation. The use of radiocarbon and Optically Stimulated Luminescence (OSL) dating of soil profiles and archaeological sites provides insights into the timeline of human-induced erosional and depositional processes and deposits ranging in age from the Palaeolithic period to the early Middle Ages. The results highlight significant soil erosion and colluvial deposit formation, especially during periods of intensified agriculture. These changes in specific soil types underscore the substantial impact of human activities and climatic variations on land relief and soil cover in the Late Holocene. This study contributes to a deeper understanding of human-driven landscape alterations in loess areas, offering valuable insights for environmental management and conservation on the Kańczuga Plateau, in the Sandomierz Basin, and in other similar geomorphological settings.

Key words: soil erosion, slope deposits, palaeosols, radiocarbon dating, Kańczuga Plateau.

INTRODUCTION

Before the arrival of early Neolithic peoples into the study area, the natural environment had been in balance. The equilibrium of the geoecosystems was disturbed by the emergence of a new geomorphological factor that exerted a growing impact over time: human activity, which from the early Neolithic period was expressed as the settlement of land and exploitation of its natural resources (Kruk, 1973; Starkel, 1995; Dotterweich, 2008).

Agricultural activity practiced by the local population, including deforestation and the use of the resulting patches of grassy, park-type open landscape for grazing by animals, may have triggered localized processes that would subsequently lead to the formation of anthropogenic chernozems (Kruk, 1973). Some researchers also maintain that chernozem soil profiles were already fully developed before the arrival of the earliest agricultural communities (Skiba and Kołodziejczyk, 2004; Łanczont et al., 2006b; Kabała et al., 2019). However, Neolithic societies did not manage to greatly transformation the landscape of the loess uplands, which remained largely covered by dense forest vegetation (Kruk, 1973). Slope sediments, which are a record of both natural denudation processes and anthropogenic ones caused by agricultural activity (deforestation, tillage, animal husbandry), accumulated at the foot of slopes on the plains bordering the bottoms of valleys (Twardy et al., 2004; Łanczont et al., 2006b; Szwarczewski, 2009; Michno, 2012).

Commonly, there are buried (fossil) soils beneath slope wash (colluvial) sediments that can be dated in order to determine the stages (phases) of soil erosion. In particular, these processes intensified at times when enhanced agricultural activity converged with natural geomorphological processes (rill-wash erosion on cultivated slopes during heavy rain and snowmelt; Starkel, 1996, 2005a; Klimek et al., 2006). Since the origins of slope wash deposits are usually associated with intensified human economic activity, a question arises: could other soil types with thick humic horizons, in addition to naturally developed profiles (mainly chernozems), have been formed as a result of a change in land use and/or a break in settlement activity?

This study:

1 – explores the spatial changes in the transformation of slopes as a result of prehistoric human activity, reflected in the type and thickness of sediments;

2 – determines the age of fossil soils and the phases of intensified slope processes.

*E-mail: pgebica@ur.edu.pl

Received: August 22, 2023; accepted January 23, 2024; first published online: March 13, 2024

STUDY AREA

LOCATION, MORPHOLOGICAL FEATURES AND LOESS COVER

The study area is located in southeastern Poland (Fig. 1A) within the Sandomierz Basin and encompasses the Subcarpathian Loess Plateau (Fig. 1B), known as the Kańczuga Plateau (Starkel 2005b), the Foremountain Loess Plateau (Malicki 1973), or the Rzeszów Foothills (Solon et al., 2018; Fig. 1C).

The study area extends as an E–W belt between Rzeszów and Przemyśl, its width ranging from 10 km in the western part to a maximum of 16 km in the central part, adjacent to the marginal zone of the Carpathian Foothills (Fig. 1B). The plateau's altitudes range from 185–190 m to 263 m a.s.l. To the north, the plateau descends a high escarpment to the Sub-Carpathian Ice Marginal Valley (Solon et al., 2018), while to the east (east of Przeworsk), it transforms into a loess terrace platform, up to 5 km wide, separated from the floodplain of the San River by a 20–30 metre-high erosion escarpment (Figs. 1C and 2E). The loess terrace south of Radymno features numerous small,

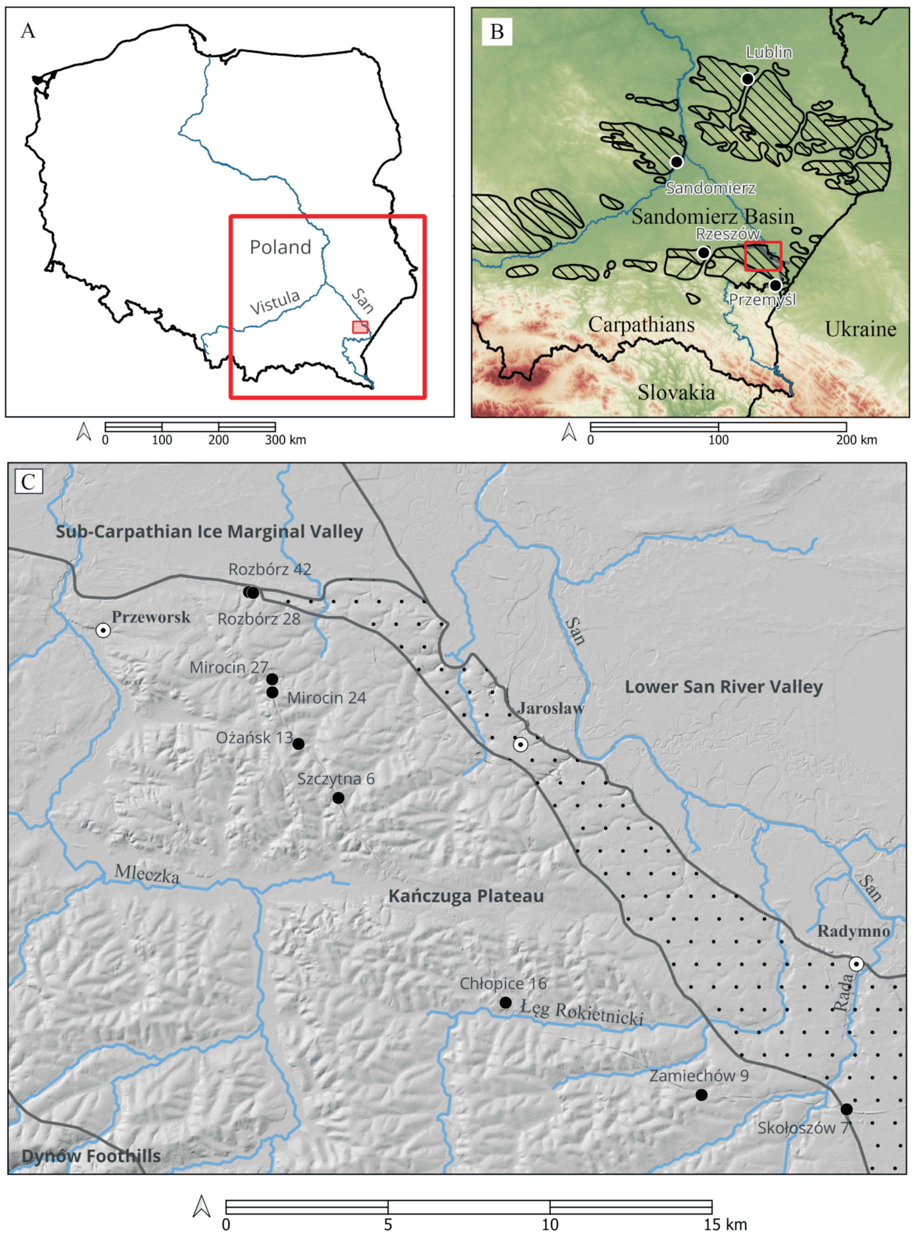

Fig. 1. Location of the study area on the map of Poland (A) and against the background of loess distribution in SE Poland (B); locations of loess patches in the Polish Uplands (Sandomierz, Lublin) and in the Sandomierz Basin are marked with a thick hatched line; loess cover in the Carpathian Foothills is marked with a sparse hatched line (my compilation based on various sources); archaeological sites and soil profiles studied, located on the Kańczuga Plateau (C); loess terrace plain is marked by dots

Source data for shaded relief model: the Country Protection Information System (ISOK) webpage, accessed via the Central Office of Geodesy and Cartography (GUGiK) on January 16, 2024 closed depressions typical of loess plateaus (known in Polish as "wymoki"), some of which are water-filled. These depressions in loess areas, filled with material from soil erosion beneath which fossil soils occur, constitute "sedimentological archives enabling the reconstruction of past natural and anthropogenic processes" (Kołodyńska-Gawrysiak, 2017). The Kańczuga Plateau is situated within the catchment basin of the San and Wisłok rivers (Fig. 1B). The plateau is dissected by two types of valley: those with permanent watercourses (the Mleczka, Rada, Łęg Rokietnicki and other rivers), 30 to 50 m deep with broad accumulative bottoms, some terraced (Figs. 1C and 2D, E); and dry, flat-bottomed valleys several kilometres long, featuring branched denudational trough-like valleys on slopes (Fig. 2B, C).

The entire plateau is covered with loess, whose thickness ranges from several to 26 metres. This loess is part of the northern European loess belt (central European continental subdomain), located to the east of the Vistula River Basin (Lehmkuhl et al., 2021). In south-east Poland, Maruszczak (1991) distinguished two regions where loess occurs: one within the southern Polish Uplands and another in the foothills region of the Carpathian foreland (Fig. 1B). The loess mainly consists of younger (Vistulian, Weichselian) loess, divided into several stratigraphic layers (Malata, 1999; Łanczont et al., 2000). Beneath the younger loess, older (pre-Vistulian) loess (Warthanian or Saalian loess) and older Pleistocene deposits (sands, clays and glacial tills) are found, providing evidence of the presence of the Scandinavian ice sheet during the San 1 (San 2?) (Elsterian) Glaciation (Łanczont et al., 2000; Marks, 2023).

SOIL CHARACTERISTICS

The presence of loess facilitated the development of fertile soils, such as chernozems and brown soils, which were then utilized by the earliest Neolithic communities in this area (Łanczont et al., 2001; Skiba and Kołodziejczyk, 2004). Dobrzański and Zbysław (1955) identified several types of chernozem in the area between the towns of Jarosław and Przemyśl, based on soil profile descriptions that focused on the thickness of the humus horizon (deep chernozem, medium-deep, shallow, washed out, and built-up chernozems). The largest areas covered by chernozems are found at elevations of 200–240 m a.s.l. and smaller areas with chernozems are limited to elevations above 240 m a.s.l., which commonly feature brown soils (Dobrzański and Zbysław, 1955). The map of soil types in Poland included in the textbook "Gleboznawstwo/Soil Science" (Mocek, 2015) also identifies brown soils (Haplic Cambisols) in higher areas

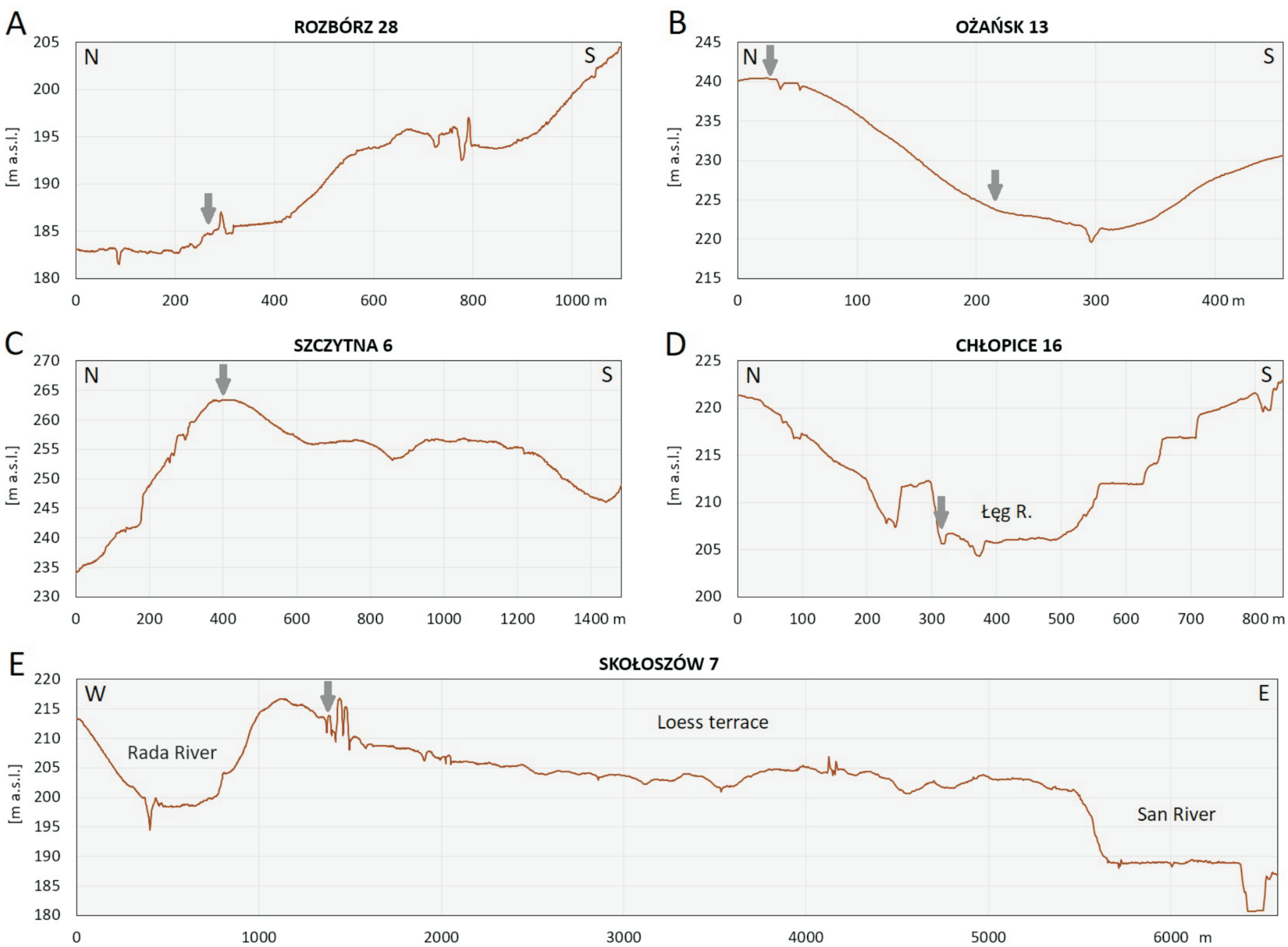

Fig. 2. Morphological cross-sections indicating archaeological sites and soil profiles: A – Rozbórz site 28, B – Ożańsk site 13, C – Szczytna site 6, D – Chłopice 16, E – Skołoszów site 7

Hypsometric profiles generated using the QGIS application

(>220–230 m a.s.l.) of the region under study and chernozems (Haplic Chernozems) in the lower eastern part of the plateau, mainly on the loess terrace. An overview of the concepts on the origin and classification of chernozems in Poland can be found in Kabała (2019).

The soil map of the Polish Carpathians, created by Skiba and Drewnik (2003), does not identify any brown soils within the study area. In contrast, the western part of the plateau, stretching between Przeworsk and Rzeszów, primarily features Luvisols (Skiba and Drewnik, 2003). These Luvisols, similar to those in the Carpathian Foothills, developed on silt deposits (loess) due to leaching (lessivage), as noted by Skiba and Szymański (2009).

PHASES OF PREHISTORIC HUMAN ACTIVITY

The Kańczuga Plateau has been inhabited by humans since the end of the Palaeolithic era and during the Mesolithic (Table 1). Early Neolithic cultures, including the Linear Pottery culture, Malice culture, and Lublin-Volhynian culture, established their settlements and camps on the overflood terraces and the lower parts of the plateau, adapting these areas for cultivation (Czekaj-Zastawny, 2008; Dębiec et al., 2015). To expand their cultivated land, the Funnel Beaker culture people engaged in intensive burning of woodlands, which led to significant local deforestation and the activation of slope (denudation) processes (Pelisiak, 2018). The Funnel Beaker culture settlements were located in areas with fertile soils (chernozems), particularly on the eastern part of the plateau, for example, the megalithic complex in Skołoszów along the Rada River (Rybicka, 2011; Król, 2018). Areas deforested by the Funnel Beaker culture were later utilized by the pastoral Corded Ware culture, whose people built burial mounds on hilltops (Jarosz and Machnik, 2017; Jarosz et al., 2019). The Bronze Age, particularly the Late Bronze Age and Early Iron Age, experienced a significant increase in the number of settlement sites (Table 1), predominantly established by the Tarnobrzeg Lusatian culture (Przybyła and Blajer, 2008; Czopek, 2011). This culture's settlements have been found on overflood terraces within the catchment areas of the Mleczka and Rada rivers, and at the edge of the loess plateau. The Roman period saw a surge in settlement activity compared to the Pre-Roman (Laten) period (Table 1; Bączalska, 2011). The settlements and burial sites of the Przeworsk culture were typically located in smaller valleys, in the lower reaches and on the foothills. Clusters of this culture's settlements were mainly concentrated on the marginal zone of the plateau and the loess terrace along the San River, and in the basins of the Rada River and the Rokietnicki Łęg River. The pattern of settlement in the early Middle Ages was similar, although the number of settlement sites was lower than during the Roman period (Parczewski, 1986; Jędrzejewska, 2019).

MATERIALS AND METHODS

SELECTION OF SITES, DESCRIPTION OF SOIL PROFILES AND ANALYSES

The selection of sites for geomorphological research was influenced by excavations conducted by archaeologists along the planned route of the A4 highway (Fig. 1C). From nearly 50 archaeological sites located along the highway between Przeworsk and Radymno (Czopek, 2011), several were chosen for soil analysis, six of which are the focus of this study (Fig. 1C).

Table 1

Distribution of archaeological sites by cultural periods and cultures: an analysis of 1418 sites spanning 860 km^2, in the Kańczuga Plateau

Archaeological sites	Absolute chronology	Kańczuga Plateau (860 km^2)	
		no	[%]
Number of sites	–	1418	100
Palaeolithic/Mesolithic	until 6000 BC	11	0.7
Linear Pottery culture (KCWR)	5500–4900 BC	62	4.2
Malice culture (KMa)	4800–3600 BC	23	1.5
Lublin-Wolynian culture (KLW)	–	9	0.5
Early Neolithic (without cultural affiliation)	–	26	1.7
Funel Baker culture (KPL)	4000–3000 BC	100	7.0
Corded Ware culture (KCS)	3000–2400 BC	101	7.1
Early Bronze Age (Mierzanowice culture)	2400–1800 BC	130	9.1
Older/Middle Bronze Age (Trzciniec culture)	1800–1300 BC	190	13.3
Late Bronze Age and Early Irone Age (Tarnobrzeg Lusatian culture-TKL)	1300–500 BC	367	25.7
Pre-Roman Period and Pomeranian culture (Laten Period)	500/400–100 BC	? a few sites	0.2
Roman Period (Przeworsk culture)	1th–5th century AD	300	21.0
Early Middle Ages	5/6th–13th century AD	114	8.0

Compiled from various sources including: Parczewski (1986, 2011), Nogaj-Chachaj et al. (2005), Czekaj-Zastawny (2008), Przybyła and Blajer (2008), Bączalska (2011), Rybicka (2011), Czopek (2011), Dębiec et al. (2015), Król (2018), Pelisiak (2018), Jarosz et al. (2019), Jędrzejewska (2019)

It is assumed that the selected sites, due to their morphological location (Fig. 2) as well as the types of soil cover and deposits, are representative not only of the A4 highway area but also of a much larger area, such as the Kańczuga Plateau.

Descriptions of the soil profiles were made on the walls of the trenches down to a depth of 2–4 metres, including the determination of soil thickness (solum) and a description of its morphological features, such as grain size, colour, horizon boundaries, structure, presence of humus, infiltrates, and precipitations of substances. Samples were taken from the profiles to complete grain-size distribution and geochemical analyses, which included the content of organic matter, calcium carbonate, soil reaction, and the content of macroelements such as iron (Fe), magnesium (Mg), calcium (Ca), sodium (Na) and potassium (K). Samples for soil texture analysis were air-dried and sieved through a 1 mm mesh. The grain-size distribution for particles smaller than 1 mm was analysed using a laser method. Gradistat software, version *5.11 PL beta*, was used to calculate statistical grain-size parameters according to Folk and Ward (1957), including mean diameter (Mz), sorting (δ_I), skewness (Sk_I), and kurtosis (K_G). The results of the analyses are shown in grain-size diagrams. Organic carbon content was determined using the Tiurin method, total iron (Fe) using atomic absorption spectrophotometry (ASA), and reaction (pH) using the potentiometric method. Palynological determinations were also conducted on several samples taken from palaeosols and peats.

Objects or features utilized by humans, such as storage pits, burial mounds, wooden structures, root cellars, tombs, furnaces, etc., along with their cultural affiliations, have been dated using archaeological methods validated by radiocarbon dating. By analysing the depths at which storage pits occur and the thickness of preserved soil profiles, it was possible to reconstruct the past topographic surface of the slope and estimate the extent of slope denudation since the onset of human activity. Due to human activities, the original soil horizons have been reduced (eroded) on the convex elements of the micro-relief, while at the foot of slopes and in depressions, there is an accumulation of material from soil erosion, contributing to the upbuilding of the soil profile (Rejman et al., 2014).

For the preparation of the morphological profiles, an airborne laser scanning elevation model (DEM), specifically *Airborne LiDAR*, was utilized. This was analysed in *QGIS* software, which was used to create the profiles. These profiles, in the form of tables (showing distance and height), were then transferred to *Excel* to create graphical representations in the form of charts.

^{14}C AND OSL DATING RESULTS

The stratigraphy of the deposits and the age of palaeosols were estimated based on radiocarbon dating, which was completed for 10 sites. This article provides the radiocarbon dating results from 6 of these sites (Table 2). Samples of organic materials, such as humus from palaeosols, peat, charcoal and wood, were dated. This typically involved taking 2–4 cm thick samples from both the tops and bottoms of palaeosols (beneath the slope wash deposits) as well as from organic interbeds within the clastic deposits. The content of organic carbon in the dated palaeosol samples ranged from 0.2 to 1.6%. Radiocarbon dating was performed using conventional methods at the Absolute Dating Laboratory in Skała near Kraków (laboratory code: MKL; Table 2).

The radiocarbon dating results were calibrated using *OxCal 4.4* software (https://c14.arch.ox.ac.uk/oxcal.html) and the *IntCal 09* calibration curve (Reimer et al., 2020; Table 2). The dates in this paper are given in radiocarbon years before the present (^{14}C BP), with the calibration indicated in parentheses (cal BC, AD), where age control is based on radiocarbon dating. The clastic deposits (sands, silts) at the Rozbórz site 28 have been dated using Optically Stimulated Luminescence (OSL). The OSL dating was performed at the Gliwice Laboratory of Luminescence Dating (Moska et al., 2021) (GdTL) (Table 3). The OSL ages shown in Table 3 are expressed in years (a) before 1950.

RESULTS

ROZBÓRZ SITES 28 AND 42

Both sites are located on the northern slope of the loess plateau, which descends to the bottom of the Sub-Carpathian Ice-Marginal Valley east of Przeworsk (Budek et al., 2013) (Figs. 1C and 2A). They are multicultural sites featuring archaeological artifacts dating from the early Neolithic period, as well as traces of late Palaeolithic and Mesolithic populations. At site 28, a palaeosol has been discovered in a denudational trough-like valley covered with slope wash deposits (Fig. 3).

The denudational trough-like valley, filled with slope wash deposits, cuts into the alluvia of the Vistulian terrace, which lies 10–12 m above the Wisłok riverbed (Gębica, 2004). The geology of the terrace was surveyed in a pit dug to a depth of 3.5 m (Fig. 4), uncovering the following layers (from top to bottom):
- 0.0–0.5 m of podzolic soil;
- 0.5–2.25 m of horizontally stratified silty sands;
- 2.25–3.50 m of sandy silts.

A sample of sands from a depth of 2.05–2.10 m yielded an OSL age of 9520 ±350 (GdTL-1134) (Table 3), and at a depth of 1.60–1.65 m, the age was 8860 ±420 (GdTL-1133). The uppermost part of the terrace, at a depth of 1.0–1.05 m, yielded an OSL age of 9680 ±380 (GdTL-1132) (Fig. 4).

Storage pits up to 1.65 m deep were cut into the stratified sandy and silty alluvia. One such pit, at a depth of 1.20 m, was filled with burnt organic material dating to 5990 ±80 BP (5100–4650 cal BC) (MKL-533) (Fig. 3). Radiocarbon dating corroborates that these features represent objects from the early Neolithic Malice culture (Budek et al., 2013). The palaeosol has a dark brown humus horizon that is 40–70 cm thick, with a greater proportion of the silt fraction towards the top and a predominance of clay towards the bottom. The content of organic carbon in the soil ranges from 1.6% at the top to 0.6% at the bottom (Fig. 5 and Table 4).

At depths from 0.95 to 1.06 m at the bottom of the profile, the content of Fe and other macroelements (Mg, Ca, Na, and K) in the soil increases significantly. A palaeosol in profile no. 4 (Fig. 3) was dated to 4100 ±80 BP (2880–2480 cal BC) (MKL-531) at its bottom and has filled a part of a storage pit (object no. 834 R19) that contained pottery from the period of the Malice and Funnel Beaker cultures (Budek et al., 2013). Therefore, the beginning of the soil formation is attributed to the late Neolithic (Corded Ware culture) and/or the early Bronze Age. In profile 1, the top of the soil has been dated to 1760 ±80 BP (70–440 cal AD) (MKL-534) (Table 2, Figs. 3 and 5). The onset of soil fossilization in the other profiles has been dated to 1230 ±60 BP (660–950 cal AD) (MKL-868) in profile 2, 1010 ±60 BP (890–1170 cal AD) (MKL-527) in profile 3 (Table 2 and Fig. 6), and 1170 ±60 BP (760–990 cal AD) (MKL-529) in profile 4 (Table 2 and Fig. 3). The oldest date (1760 ±60 BP) suggests that the fossilization of the soil in profile 1 began during the Roman

Table 2

Radiocarbon dating outcomes for fossil soils, peats and wooden platforms at archaeological sites across the Kańczuga Plateau

Site name and profile no.	Depth [m]	Type of material	Facies of deposits	Laboratory no.	Radiocarbon age [BP]	Calibrated age [BC/AD] (9.4%)
Rozbórz 28/1**	1.10–1.12	humic silt	palaeosol	MKL-534	1760 ±80	70–440 AD
Rozbórz 28/2	0.95–0.97	humic silt	palaeosol	MKL-868	1230 ±60	660–950 AD
	1.20–1.23	humic silt		MKL-869	3780 ±90	2500–1950 BC
Rozbórz 28/3	1.42–1.44	humic silt	palaeosol	MKL-527	1010 ±60	890–1170 AD
	1.70–1.72	humic silty clay		MKL-528	3970 ±70	2850–2200 BC
Rozbórz 28/4**	1.10–1.13	humic silt	palaeosol	MKL-529	1170 ±60	760–990 AD
	1.48–1.50	humic silty clay	palaeosol	MKL-532	4090 ±90	2900–2450 BC
	1.65–1.68	humic silty clay	fill of storage pit	MKL-531	4100 ±80	2880–2480 BC
Rozbórz 42/3	0.90–0.95	humic silt	palaeosol	MKL-752	4360 ±70	3330–2870 BC
Rozbórz 42/5	1.08–1.12	humic silt	palaeosol	MKL-866	1820 ±50	70–340 AD
	1.25–1.30			MKL-804	1040 ±60	880–1160 AD
Ożańsk 13	1.40–1.45	humic silt	palaeosol	MKL-806	7980 ±90	7140–6640 BC
Ożańsk 13/6	1.0–1.05	humic silt	colluvia	MKL-537	1340 ±80	560–890 AD
Ożańsk 13/1*	1.12–1.14	humic silt	palaeosol	MKL-291	12840 ±100	13650–12850 BC
Szczytna 6	0.40–0.45	humic silt	palaeosol	MKL-870	4795 ±70	3710–3370 BC
1/E	0.40–0.45	humic silt	palaeosol	MKL-871	4210 ±70	2930–2570 BC
2/W						
Chłopice 16***	0.90–0.92	humic silt	colluvia	MKL-865	1720 ±60	130–440 AD
	1.25–1.27	humic silt	palaeosol	MKL-803	2240 ±60	410–160 BC
	1.67–1.68	humic silt	palaeosol	MKL-805	5210 ±70	4240–3800 BC
Chłopice 16/1***		peat	palaeochannel fill	MKL-622	1390 ±40	570–690 AD
		peat		MKL-621	6350 ±90	5490–5060 BC
		peat		MKL-620	6840 ±100	5980–5560 BC
Chłopice 16, CHL5_W10***		wood (beam)	fragment of wooden platform	MKL-623	1560 ±40	410–590 AD
Skołoszów 7	0.75–0.80	humic silt	palaeosol	MKL-538	4490 ±120	3550–2850 BC
	1.15–1.20	humic silt	palaeosol	MKL-539	6920 ±90	5990–5650 BC

Table 3

OSL dating of fluvial deposits at Rozbórz site 28, profile 6

Site name and profile no.	Depth [m]	Type of material	Laboratory code	OSL age (a)
Rozbórz 28 6/1	1.0–1.05	silty sand	GdTL-1132	9680 ±380
Rozbórz 28 6/2	1.60–1.65	silty sand	GdTL-1133	8860 ±420
Rozbórz 28 6/3	2.05–2.10	silty sand	GdTL-1134	9520 ±350

period (1st–5th century AD). In the next three profiles, younger dates at the top of the soil indicate the formation of the slope wash deposits during the early Middle Ages (7th–11th century AD). The slope wash deposits were laid down at the foot of the slope in a strip 200–300 m wide. The thickness of the colluvial deposits ranges from 0.9 to 1.4 m. This cover consists of silts with a large proportion of sand. The mean grain-size diameter ranges from 4.5 to 5.8 φ. The material is poorly to very poorly sorted. In profile 1, the pH increases from 7 to 7.6 down to a depth of ~1 m, then drops <7 in the humic horizon of the palaeosol at a depth of 1.06–1.15 m. Apart from the uppermost sample, the content of organic carbon in the slope wash cover does not exceed 0.4% (Fig. 5 and Table 4). In terms of grain size and structure, the slope wash deposits are divided into two lithological units (Fig. 6): (1) an older (lower) unit, up to 60 cm thick, deposited directly on the palaeosol, includes horizontally stratified silts and sands with layer thicknesses ranging from 1 to 11 cm, its upper part being slightly irregular, and (2) a younger (uppermost) unit composed of silt-sand deposits up to 80 cm thick (with an arable layer on top), its internal structure obliterated by soil-forming processes.

At site 42 in Rozbórz, the sedimentary profiles were surveyed to the north of the plateau's edge, dissected by small denudational trough-like valleys and routes (holwegs) with extensive colluvial fans deposited at their outlets. Beneath the colluvial deposits, a palaeosol similar to organic soil or heavily decomposed peat soil with a black humus horizon was found. A soil sample analysed for palynological content by K. Szczepanek showed the presence of grass, pine, poplar, fern, spruce, willow, birch, alder, hazel, oak and elm pollen grains. This composition of the pollen spectrum may indicate the Atlantic period. A soil sample taken from a depth of 0.90–0.95 m has been dated to 4360 ±70 BP (3330–2870 cal BC) (MKL-752) (Table 2), indicating the Sub-Boreal period. Unfortunately, the beginning of the fossilization of organic soil at site 42 could not be determined because the radiocarbon dates, 1040 ±60 BP

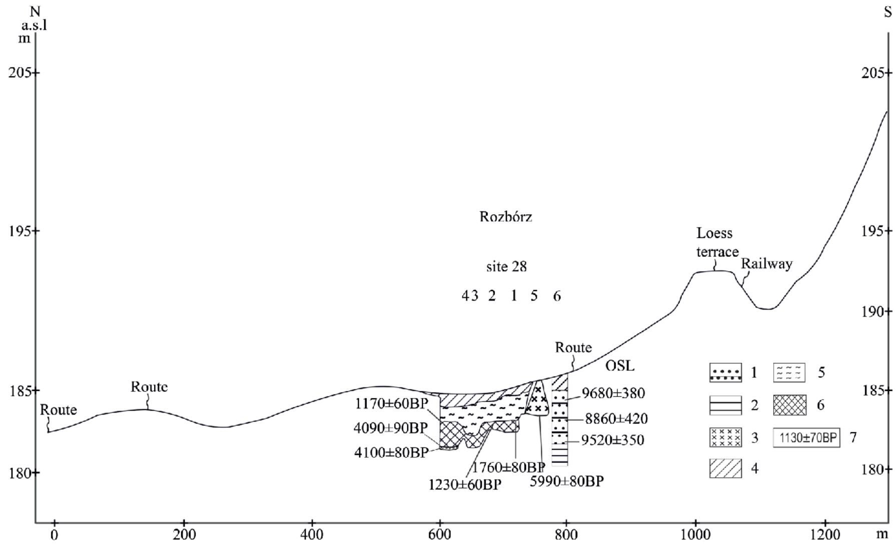

Fig. 3. Cross-section of the northern slope of the Kańczuga Plateau

Fossil soil, slope deposits and alluvial deposits with radiocarbon and OSL dating; Rozbórz site 28 near Przeworsk; 1 – sand, 2 – silt (mud), 3 – storage pit, 4 – soil (arable horizon), 5 – slope wash (colluvial) deposits, 6 – fossil soil, 7 – radiocarbon dating points

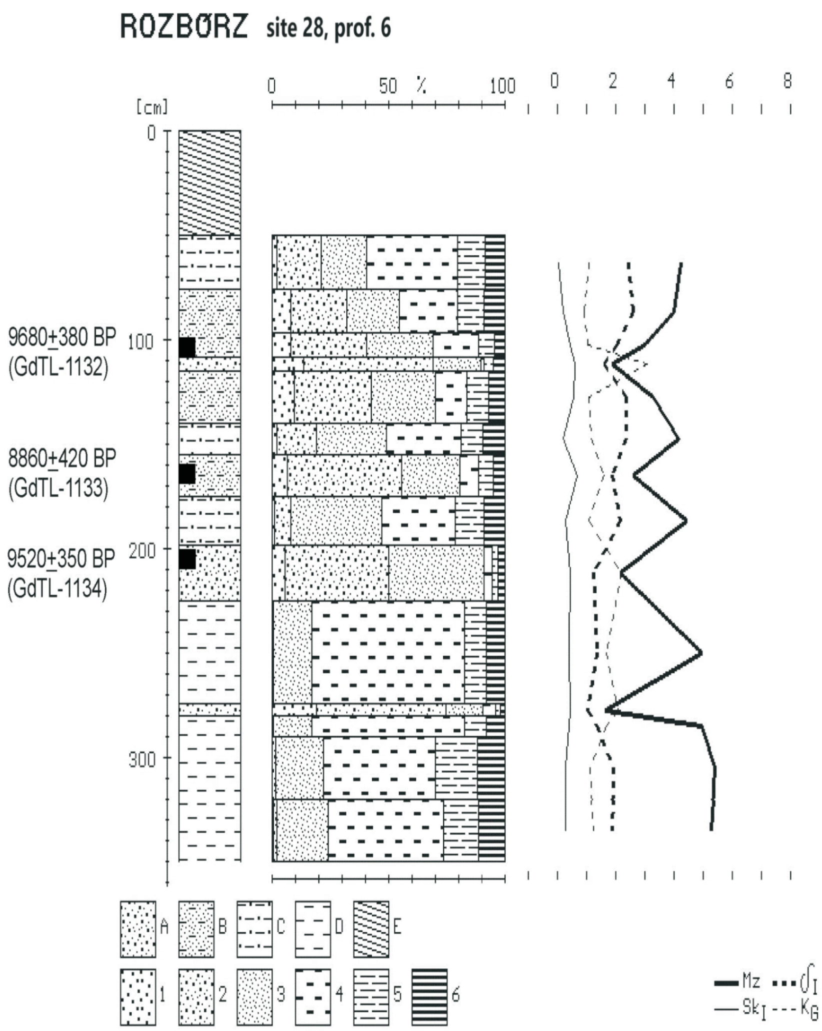

Fig. 4. Alluvial deposits of the Wisłok River dated by OSL at Rozbórz site 28, profile 6

Lithology and grain-size indices after Folk and Ward (1957); lithology: A – medium sand, B – silty sand, C – sandy silt, D – silt (mud), E – Holocene soil; granulometry: 1 – coarse sand (Mz = –1 to +1 phi), 2 – medium sand (Mz = +1 to +2 phi), 3 – fine sand (Mz =+2 to +4 phi), 4 – coarse silt (Mz =+4 to +6 phi), 5 – fine silt (+6 to +8 phi), 6 – clay (Mz >8 phi); Mz – mean grain size, σ_I – standard deviation, Sk_I – skeweness, K_G – kurtosis

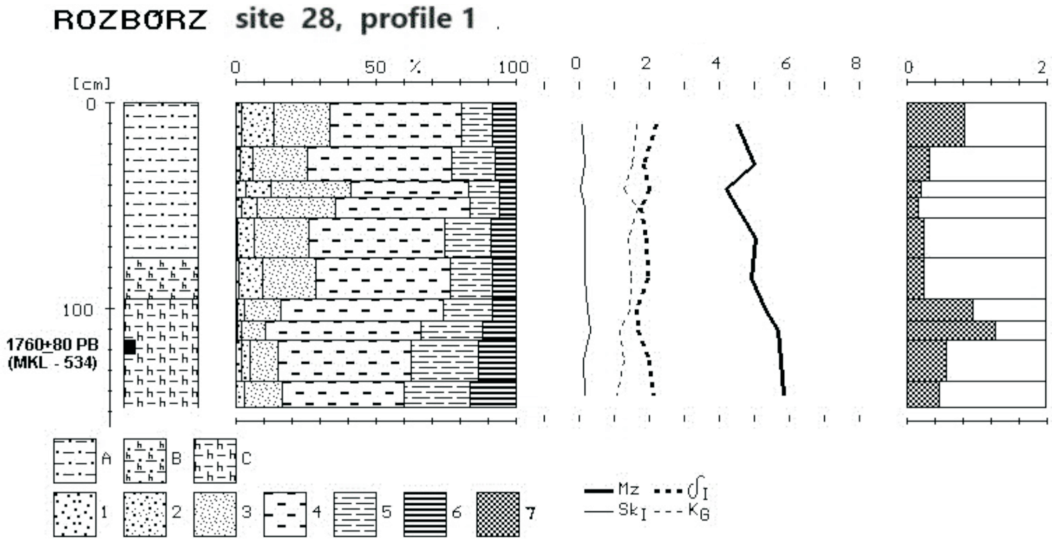

Fig. 5. Lithology, granulometry, grain-size indices and content of organic carbon in fossil soil and colluvial deposits at Rozbórz site 28, profile 1

Lithology: A – sandy silt, B – sandy silt with organic matter, C – organic silt; granulometry: 1 – coarse sand (Mz = –1 to +1 phi), 2 – medium sand (Mz = +1 to +2 phi), 3 – fine sand (Mz = +2 to +4 phi), 4 – coarse silt (Mz = +4 to +6 phi), 5 – fine silt (Mz = +6 to +8 phi), 6 – clay (Mz >8 phi), 7 – content of organic carbon; Mz – mean grain size, σ_I – standard deviation, Sk_I – skeweness, K_G – kurtosis

Table 4

Grain-size indices, pH, organic carbon content, Fe and selected macroelements of fossil soil and slope wash deposits at Rozbórz site 28, profile 1

Depth	pH		Corg.	Macroelements [mg/kg]					Grain-size indices			
[m]	H_2O	KCl	[%]	Fe	Mg	Ca	Na	K	Mz	σ_I	S_K	K_G
0–0.21	7.2	7.0	1	6788	1231	2765	123	1755	4.51	2.19	0.07	1.64
0.21–0.38	7.0	5.9	0.4	7459	1385	1917	98	1608	5.01	1.84	0.18	1.52
0.38–0.46	7.1	6.0	0.3	5867	1010	1454	94	1211	4.21	2.0	0.05	1.27
0.46–0.56	7.2	6.1	0.2	6188	1043	1492	98	1163	4.51	1.76	0.15	1.67
0.56–0.75	7.5	6.2	0.3	6609	1094	1542	114	1379	5.06	1.94	0.18	1.4
0.75–0.95	7.4	6.4	0.3	7521	1285	1675	142	1493	4.93	1.97	0.16	1.49
0.95–1.06	7.6	6.3	1.2	18671	1968	3546	162	1974	5.32	1.63	0.25	1.44
1.06–1.15	7.0	6.2	1.6	22250	1793	4325	162	2000	5.69	1.97	0.34	1.16
1.15–1.35	7.2	6.0	0.9	33925	2194	3492	170	2361	5.76	2.0	0.14	1.28
1.351.48	7.6	6.0	0.6	84371	2673	3934	187	2743	5.83	2.13	0.18	1.06

(880–1160 cal AD) (MKL-804) at a depth of 1.25–1.30 m, and 1820 ±50 BP (70–340 cal AD) (MKL-866) at a depth of 1.08–1.12 m, exhibit an age inversion.

OŻAŃSK SITE 13

The section shown in Figure 7 originates from the southern slope of the upper stretch of a denudational valley (Fig. 2B) in the catchment basin of the San River, where archaeological features and soil profiles surveyed – both those with a humus horizon of the palaeosol preserved *in situ* and those with slope wash deposits – are marked. As determined by radiocarbon dating, the oldest storage pits located on the top of the plateau represent the Neolithic period (Malice culture, Funnel Beaker culture, and Corded Ware culture). Younger storage pits come from the Bronze Age and the early Iron Age, and the most recent features (furnaces, clay pit) in the lower part of the slope date back to the early Middle Ages (Wilk et al., 2013).

In profile 5, under the arable layer (Ap) and humic silty slope wash deposits at a depth of 0.66–1.0 m, there is a layer of black humus silt (horizon A). Departing from this at a depth of 1.0 m are cracks 20 cm long and 3–8 cm wide, filled with humus. These cracks dissect the compact silty clay (Bbr horizon?) lying beneath. They form an irregular network of small polygons on the surface, likely resulting from the drying of the ground. A sample of humus taken from one of the profiles at a depth of 1.40–1.45 m has been dated to 7980 ±90 BP (7140–6640 cal BC) (MKL-806) (Table 2), indicating the Atlantic period. Except for single pine and hornbeam pollen grains and signs of a fire,

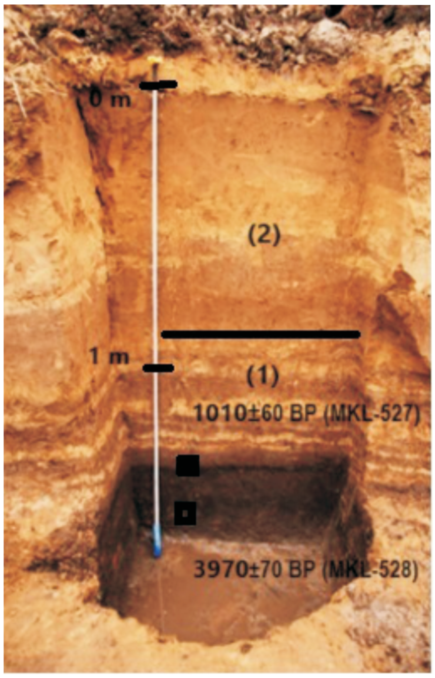

Fig. 6. Rozbórz site 28, profile 3

The structure of slope wash deposits and radiocarbon age of the buried soil accumulated at the foot of the loess plateau. Lithological units (1) and (2) in the colluvial deposits are described in the text. Dating of the buried soil at the top – 1010 ±60 BP (MKL-527) indicates that the colluvial deposits in this profile accumulated in the early Middle Ages (9th–12th century AD)

these soils contain no pollen grains. In profile 1, as shown in the section (Fig. 7), a 50 cm thick fossil humus horizon of chernozem has been found beneath slope wash deposits at a depth of 1.12–1.14 m, dated to 12 840 ±100 BP (13 650–12 850 cal BC) (MKL-291) (Gębica et al., 2010). This date, if not overestimated, suggests that the soil formation began in the Late Vistulian (Bølling) period. The distribution of storage pits and graves in the upper part of the slope (above profile 8), beneath the topsoil, shows that both the original soil cover and the storage pits have been eroded. In the local depressions with preserved chernozems, loess colluvial material has accumulated. Objects such as clay pits and ovens located in the middle and especially the lower part of the slope were overlain by slope wash deposits up to 2 metres thick.

SZCZYTNA SITE 6

Located on top of a hill (263 m a.s.l.) (Fig. 2C), the archaeological site in Szczytna features a burial mound ~1–1.5 m high, erected by late Neolithic people of the Corded Ware culture (Machnik, 2011). Since its creation, the mound has been largely levelled by natural denudation processes and ploughing. The remnants of the burial mound, measuring 25 x 25 m, are covered with contemporary soil (an arable horizon) under which a fossil humus horizon of older Holocene soil, used to build the mound, has been exposed. The soil profiles on the eastern and western parts of the top of the barrow reveal (from top to bottom):

– a silty arable layer (Ap);
– black humus silt (A horizon of the palaeosol) ranging in thickness from 0.25 to 0.47 m;
– decalcified brown-yellow silt (illuvial Bt horizon?);
– calcified loess 1.1–1.2 m.

The humic horizon in the eastern profile has been dated to 4795 ±70 BP (3710–3370 cal BC) (MKL-870) (Table 2). In the western profile, the humic horizon fills a storage pit descending to a depth of 0.5–0.8 m. Humus in this profile, found at a depth of 0.40–0.45 m, was dated to 4210 ±70 BP (2930–2570 cal BC) (MKL-871) (Table 2). A very similar date of 4320 ±90 BP (3335–2672 cal BC) (MKL-1033) has been established for a grave under the mound, corroborating its association with the Corded Ware culture (Jarosz and Machnik, 2017). Profiles outside the mound lack a fossil humic layer but instead feature stratified silt deposits.

CHŁOPICE SITE 16

The profiles surveyed were located below archaeological site no. 16 in Chłopice, on the slope of the Łęg Rokietnicki River Valley (a tributary of the San River), which faces south (Fig. 2D). The lithological profile at the foot of the slope includes loess and humus slope wash deposits overlying a palaeosol dated to the Atlantic period. The bottom of the soil at a depth of 1.67 m has been dated to 5210 ±70 BP (4240–3800 cal BC) (MKL-805), and the top at a depth of 1.25 m to 2240 ±60 BP (410–160 cal BC) (MKL-803) (Table 2). The soil is covered with a 30 cm thick layer of silty slope wash deposits and humus, dated to 1720 ±60 BP (130–440 cal AD) (MKL-865) at a depth of 0.90 m (Gębica, 2015). The youngest date in the profile suggests that the activation of the slope covers began in the Roman period, as corroborated by the presence of hearths (furnaces) used by people of the Przeworsk culture at the site (Jędrzejewska and Wilk, 2015). In the early Middle Ages, slope denudation intensified, as indicated by wooden structures covered by slope wash deposits. Archaeologists made a significant discovery in the peaty bottom of the Łęg Rokietnicki River at a depth of ~2 m, finding a wooden bridge (platform) dated to 1560 ±40 BP (410–590 cal AD) (MKL-623), built by the inhabitants of an early Slavic settlement in Chłopice (Jędrzejewska and Wilk, 2015). Boreholes have shown that the bottom of the valley is filled with peat dated to 6840 ±100 BP (5980–5560 cal BC) (MKL-620) at a depth of 2.57–2.64 m and to 6350 ±90 BP (5490–5060 cal BC) (MKL-621) at a depth of 2.42–2.50 m (Gębica, 2015). This indicates that the accumulation of these organic deposits dates back to the Atlantic period. Except for pine, alder, fern, and isolated birch and hornbeam pollen grains, the peat did not contain any detectable plant pollen grains, so the composition of the natural vegetation and crops cultivated by the people at that time remains unknown.

SKOŁOSZÓW SITE 7

The profiles described are located below archaeological site no. 7 in Skołoszów (Rybicka, 2011; Król and Niebieszczański, 2019), on a gentle slope inclined towards a loess terrace, ~200–300 m east of the Rada River Valley (Figs. 1C and 2E). The profile in the lower stretch of the slope was close to a drainless depression (Polish "wymok") filled with water. Under a 0.7 m thick layer of loess slope wash deposits, the survey uncovered dark brown/black compact humus silt (A horizon) of the

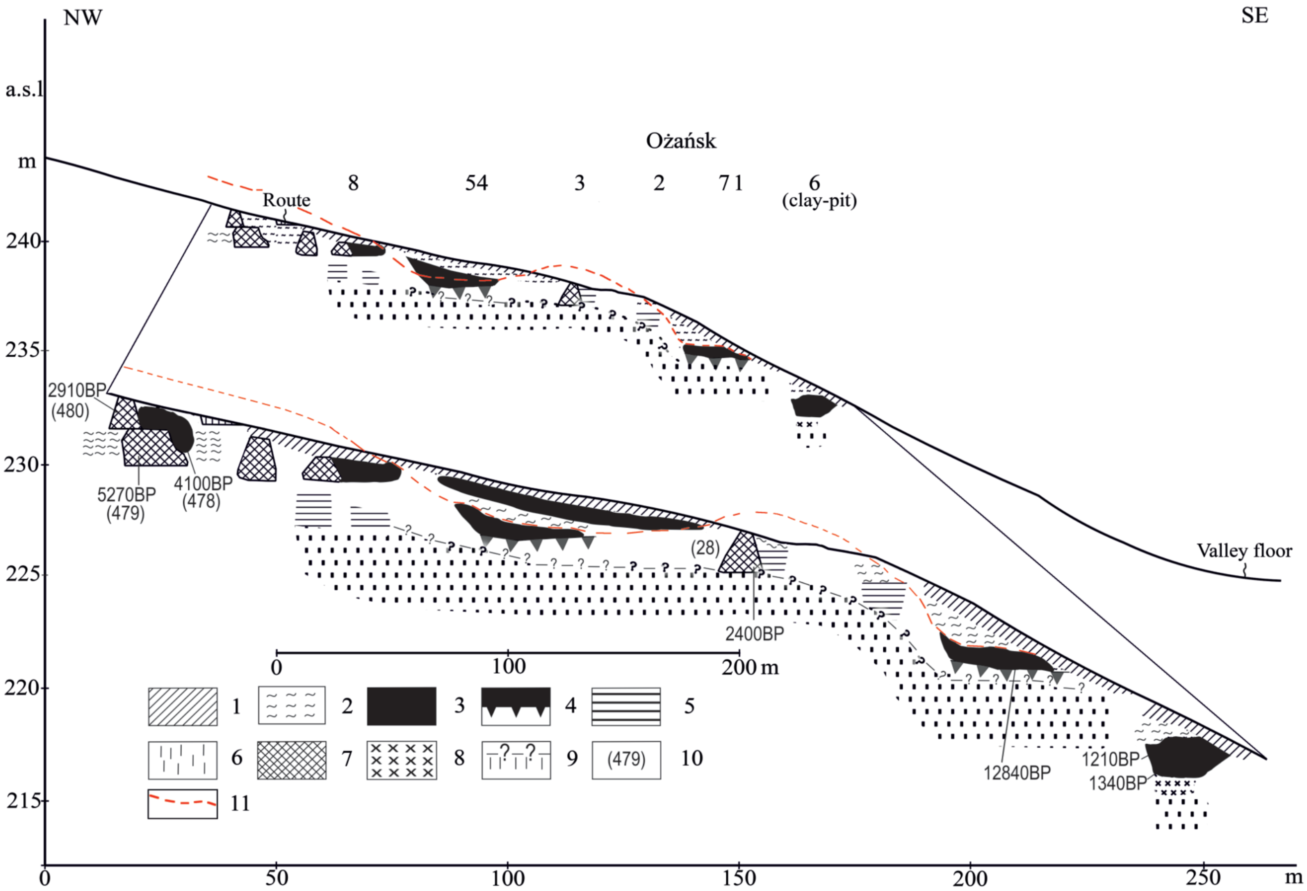

Fig. 7. Cross-section of Ożańsk site 13: archaeological features, fossil soil profiles and slope deposits

Numbers without parentheses with BP mark ^{14}C dating (not calibrated); the numbers above the cross-section correspond to the soil profiles identified and provide reference to their specific locations within the site; 1 – soil (arable horizon) with recent surface (solid line), 2 – slope wash silts, 3 – slope wash humic horizons, 4 – fossil humic horizon of chernozem *in situ*, 5 – stratified loess, 6 – massive loess, 7 – storage pits, 8 – cultural layers with artefacts, 9 – supposed depth of loess unaltered by the soil processes, 10 – number of storage pit, 11 – reconstructed primary surface of slope

palaeosol, which reaches down to a depth of 1.2 m, then transforming into yellow-orange decalcified loess (Bt horizon?) with cracks filled with humic material to a depth of 1.45 m. The dating of the humus horizon at the base of the palaeosol at a depth of 1.15–1.20 m yielded an age of 6920 ±90 BP (5990–5650 cal BC) (MKL-539) (Table 2), attributing it to the Atlantic period. The age of the sample from the uppermost part of the soil at a depth of 0.75–0.80 m is 4490±120 BP (3550–2850 cal BC) (MKL-538). The slope wash deposits covering the fossil soil can be attributed to the activities of a settlement of the Funnel Beaker culture, which was located here (Rybicka, 2011; Król, 2018; Król and Niebieszczański, 2019).

INTERPRETATION AND DISCUSSION

AGE OF CHERNOZEMS ON THE SUBCARPATHIAN LOESS PLATEAU

In the early Holocene, with the cool and dry climate that prevailed at the time, chernozems developed on loess under forest and grass vegetation (Vysloužilova et al., 2014). It cannot be ruled out that the chernozems had already formed in the Late Vistulian. This is implied by radiocarbon dating of 12 840 ±100 BP (13 650–12 850 cal BC) (MKL-291) (Gębica et al., 2010) for a fossil humic horizon in Ożańsk (Fig. 7). A similar dating result, indicating the beginnings of chernozem formation in the late Vistulian, was obtained from buried humic soil in the Sudeten Foreland (Kabała et al., 2019). By the time early Neolithic farmers began cultivating the land in the climatic optimum of the Holocene (the Atlantic period), the profiles of the chernozems were already fully developed (mature soils). This is indicated by the radiocarbon dating of humic substances sampled from the base of fossil chernozems in Ożańsk (7980 ±90 BP, 7140–6640 cal BC) (MKL-806), Skołoszów (6920 ±90 BP, 5990–5650 cal BC) (MKL-539), and Chłopice (5210 ±70 BP, 4240–3800 cal BC) (MKL-805). The age of the deposits filling the bottom of the Łęg Rokietnicki Valley (6840–6350 BP, 5980–5060 cal BC) (Gębica, 2015) and the Rada Valley (6780 BP) (Kalicki, 1998) suggests that both chernozem soils on the slope and organic deposits in the valley floors were formed during the Atlantic period. Dating of humus in palaeosols can yield erroneous results due to the continuous mixing of humic material during soil formation. Therefore, the results of dating should be treated as average age values, closer to the end of the humus accumulation interval rather than to the beginning of the soil formation process (Gębica, 1995; Kabała et al., 2019).

Problem of the origin, age, and evolution of soils in loess areas is more complex. Observations of some palaeosols underlying colluvial deposits show that these soils may have features of a soil pedocomplex (two soils superimposed on each other), representing two cycles of soil process development: an older one from the forest phase (Luvisol) and a younger one which features a superimposed humic soil horizon (meadow soil) (Łanczont et al., 2006b). These observations are corroborated by age determinations using TL (thermoluminescence) on the illuvial (Bt) horizon of a fossil soil at 11,200–10,800, suggesting that the formation of Luvisol on the loess of the Kańczuga Plateau should be dated to the Alleröd. This soil was subject to denudation processes in the Late Vistulian, and the humus horizon (superimposed on the Luvisol), TL-dated to 9100, probably represents a younger, Preboreal phase of soil development (Łanczont et al., 2006b).

NEOLITHIC – THE BEGINNING OF DEGRADATION OF THE SOIL COVER

The arrival of farming populations from the Funnel Beaker culture initiated the degradation of the chernozems and the activation of slope covers. The depth of erosion in storage pits and soil profiles, as well as the occurrence of buried chernozem in closed depressions at the Ożańsk site, enabled the reconstruction of the old topographic surface of the slope (Fig. 7). Soil cover and storage pits located on the upper part of the hillslope were subject to erosion, while colluvial sediments accumulated in small depressions, preserving the chernozems. These processes gradually smoothed the original undulose surface of the slope. The estimated amount of denudation on the slope since the beginning of settlement in Ożańsk is between 0.5 and 1.0 metres. However, these processes did not extend to larger loess areas but were confined to isolated patches near large settlements of the Funnel Beaker culture (Rybicka, 2011; Król, 2018; Król and Niebieszczański, 2019). Research results similar to those at the Ożańsk site, aimed at reconstructing the original slope surface based on pedological analysis, were obtained at archaeological sites in the central part of Roztocze (Rodzik et al., 2017) and in the Lublin Upland (Rodzik et al., 2014). The onset of chernozem fossilization and the filling of a closed depression (“wymok”) on the loess terrace, dated to 4490 ±120 BP (3550–2850 cal BC) (MKL-538), are associated with the existence of a large megalithic settlement of the Funnel Beaker culture in Skołoszów (Rybicka, 2011; Król and Niebieszczański, 2019). Similar dating results (using OSL and ^{14}C methods), documenting the onset of soil erosion during the activity of the Funnel Beaker culture, come from colluvial deposits filling closed depressions on the loess Nałęczów Plateau in eastern Poland (Kołodyńska-Gawrysiak et al., 2017). Loess uplands and hills deforested by the Funnel Beaker culture were used by shepherd tribes of the Corded Ware culture, who built burial mounds at the top of the hill in Szczytna (Jarosz and Machnik, 2017) and most likely also in the area of Cieszacin Wielki (Łanczont et al., 2003). Niche graves of the Corded Ware culture discovered in Mirocin on the flat hilltop (Mazurek and Sznajdrowska, 2016; Fig. 1C) may indirectly indicate the existence of barrows there, now completely destroyed (Jarosz et al., 2019). The reconstruction of the occurrence of primary chernozem and soil formed on the mound indicates that the mound embankment lost ~0.5–1.0 meters to erosion by natural and anthropogenic denudation processes. The radiocarbon date of 4210 ±70 BP (2940–2585 cal BC) (MKL-871) ascribed to chernozem humus sampled from the mound at a depth of 0.45 meters corroborates that the mound and the burials are attributable to the Corded Ware culture (Jarosz and Machnik, 2017).

AGE OF SLOPE DEPOSITS AND BURIED SOIL AT THE FOOT OF THE SUBCARPATHIAN LOESS PLATEAU

On the northern slope of the Kańczuga Plateau in Rozbórz, a humus horizon of buried soil, dated to the late Neolithic and/or early Bronze Age (4100–3970 BP, 2880–2200 cal BC), overlies the bottom of a fossil denudational trough-like valley covered with slope wash deposits (Fig. 3). This denudational trough-like valley cuts into the sandy and silty alluvia of the Wisłok River, for which OSL dating has given ages of 9520 ±350 (GdTL-1134) at the bottom and 9680 ±380 (GdTL-1132) at the top (Table 3). Despite the age inversion, likely caused by rapid sediment deposition and the resultant incomplete zeroing (bleaching) of the OSL signal in sandy sediments, all three dates suggest accumulation during the early Holocene. From a geomorphological viewpoint, the OSL age of the fluvial deposits in Rozbórz is slightly underestimated compared to the dating of the alluvium of the Vistulian terrace of the Wisłok River (Gębica, 2004). The humic horizon of the soil was overlain by silt-sand colluvial deposits, 0.9–1.40 m thick. The progradation of small colluvial cones occurred successively from the Roman Period to the early Middle Ages (7th–11th centuries AD) (Budek et al., 2013) (Fig. 3). Paradoxically, no artifacts or structures indicative of early Medieval settlement have been found near the dated profiles. Rather, the area was used as farmland at that time. Interestingly, the beginning of soil formation in Rozbórz, dated to ~4300–4000 BC, coincides with a distinct phase of flooding and water level surges identified in the Vistula Valley east of Kraków (Kalicki et al., 1996) and on the periphery of the peatbog area covered by the alluvial fan of the Słocina Stream in Rzeszów (Starkel et al., 2002). The alluvial clays overlying the Preboreal peat in the Wisłok palaeochannel in Gniewczyna Łańcucka to the north of Jarosław town (Gębica, 2011) have been dated to the same time (3970 ±60 BP).

In the lowest part of the slope at the Ożańsk site, a layer with early Medieval artifacts has been found beneath humic slope wash deposits at a depth of 1.5–2.1 m. The dating of the soil slope wash deposits above the artifact layer to 1340 ±80 BP (560–890 AD) (MKL-537) and 1210 ±70 BP (MKL-536) (Table 2 and Fig. 7) suggests that the colluvial deposits were activated in the 6th–9th centuries AD, i.e., at the same time as in Rozbórz near Przeworsk. In Chłopice, on the slope of the Łęg Rokietnicki Valley, denudational processes and soil fossilization were initiated in 2240 ±60 BP (410–160 cal BC) (MKL-803), i.e., during the Pre-Roman Period (Laten Period), but the thickest humic slope wash deposits accumulated in the Roman period (1720 ±60 BP, 130–440 cal AD) (MKL-865) (Gębica, 2015). A hearth used by the people of the Przeworsk culture, covered by 1.5 m thick slope deposits, dates to that period (Jędrzejewska and Wilk, 2015). Surveys on the valley floor of the Łęg Rokietnicki revealed fragments of a wooden bridge (platform) at a depth of 1.5–2.0 m, dated by dendrochronology and ^{14}C to the second half of the 9th century AD, associated with an early Slavonic settlement (Jędrzejewska and Wilk, 2015). An alluviation process (upbuilding of valley bottoms), documented in alluvial-fan deposits in a tributary of the Mleczka Wschodnia River, is primarily attributed to the activation of slope covers as a result of deforestation in the early Middle Ages (Klimek et al., 2006; Łanczont et al., 2006a). Similar evidence of valley filling and intensive progradation of colluvial/alluvial fans in the Roman period and the early Middle Ages has been found in loess areas of the Little Poland

(Małopolska) Upland (Śnieszko, 1995; Szwarczewski, 2009; Michno, 2012) and the Głubczyce Plateau in the upper Oder River Basin (Zygmunt, 2004).

CONCLUSIONS

The conclusions drawn from this study highlight the impact of human activities and natural processes on the landscape evolution over time. Key findings include:

1. The scale of anthropogenic transformations of slopes over the period investigated varied spatially but the amount of soil erosion was not significant. The periods of slope relief transformation and the build-up of valley bottoms coincided with the development of prehistoric cultures, which may imply that the development of the relief and soil cover in the Late Holocene was driven by anthropogenic pressures. Climate fluctuations may have intensified the transformation of terrain relief and influenced the dynamics of man-made denudation processes.

2. By the time Neolithic farmers arrived in the area, the chernozem profiles on the Kańczuga Plateau had already fully developed, a fact corroborated by surveys on the Proszowice Plateau (Skiba and Kołodziejczyk, 2004). The reconstructed original slope surface at the Ożańsk site shows that locally, the amount of denudation within the Kańczuga Plateau area ranged between 0.5 and 1 m, while the accumulation of sediments at the foot of slopes and in the bottoms of valleys did not exceed 2 m.

3. The activation of the slope covers, which are 1–2 m thick, mainly dates to the Roman period and the early Middle Ages. Texturally, these are silty-sandy deposits characterized by coarser grains and a lower content of organic matter and macroelements compared to the buried soil.

4. The change in land use (using land as pasture instead of for cultivation) or a break in the settlement at the end of the Neolithic and/or early Bronze Age halted denudation processes and led to the formation (~4000 BP) of a humic horizon in the soil at the foot of the northern slope of the Kańczuga Plateau (in Rozbórz).

Acknowledgements. I wish to thank my colleagues, archaeologists from the Institute of Archaeology of the University of Rzeszów and other institutions and companies, for their help in field surveys, for scientific discussions, and for sharing the latest literature and unpublished archaeological studies relevant to the research area. K. Szczepanek from the Botanical Garden of the Jagiellonian University in Kraków is acknowledged for palynological analysis of several samples. I thank T. Tokarczyk from the Institute of Archaeology of the University of Rzeszów for graphical preparation of figures 1, 3, and 7. A. Budek is acknowledged for graphical preparation of figures 4, 5, and table 4 from the Rozbórz 28 site. M. Sobucki from the Institute of Geography and Spatial Management of the Jagiellonian University is acknowledged for graphical preparation of figure 2. I am grateful to P. Pilch and M. Cahn for the linguistic correction of the article. I would like to give thanks to L. Dubis and two anonymous reviewers for constructive comments which improved the content of the article. I thank the Editors very much for all suggestions and advices, and corrections of English language concerning the revised form of the manuscript which have helped me to improve and clarify the text of the article. The research and analyses have been financed by the Rzeszów Archaeological Centre Foundation.

REFERENCES

Bączalska, I., 2011. Osadnictwo okresu rzymskiego na Podgórzu Rzeszowskim (in Polish). MSc Thesis, Institute of Archaeology, University of Rzeszów.

Budek, A., Gębica, P., Okoński, J., 2013. Geoarchaeological studies of humic soil horizons and anthropogenic infillings at the multicultural archaeological excavation Site 28 in Rozbórz near Przeworsk, Southern Poland. Archaeologia Polona, **49**: 121–133.

Czekaj-Zastawny, A., 2008. Settlement of Linear Pottery Communities in the Upper Vistula River Basin (in Polish with English summary). IAE PAN, Kraków.

Czopek, S. ed., 2011. Motorway to the past. Exhibition Catalogue (in Polish with English summary). Muzeum Okręgowe w Rzeszowie.

Dębiec, M., Dębiec, M., Pelisiak, A., 2015. Cieszacin Wielki, site 41, Pawłosiów, site 55, Jankowice, site 9. Complex of settlements from the Neolithic and Early Bronze Age (in Polish with English summary). Archaeologica Ressoviensia **9**, FROA.

Dobrzański, B., Zbysław, B., 1955. Czarnoziemy na lessach Podkarpacia (in Polish). Annales UMCS, Sec. E, **10**: 287–299.

Dotterweich, M., 2008. The history of soil erosion and fluvial deposits in small catchments of central Europe: deciphering the long-term interaction between humans and the environment – a review. Geomorphology, **101**: 92–108. https://doi.org/10.1016/j.geomorph.2008.05.023

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

Gębica, P., 1995. Evolution of the Vistula River valley between the Nowe Brzesko and Opatowiec in the Vistulian and Holocene (in Polish with English summary). Dokumentacja Geograficzna, **2**: 1–91.

Gębica, P., 2004. The course of fluvial accumulation in the upper Vistulian in the Sandomierz Basin (in Polish with English summary). Prace Geograficzne, **193**: 1–229.

Gębica, P., 2011. Stratigraphy of alluvial fills and phases of the Holocene floods in the lower Wisłok river valley, SE Poland. Geographia Polonica, **84**, Special Issue Part I: 39–60.

Gębica, P., 2015. Geomorphological characteristic and stratigraphy of deposits on the site 16 in Chłopice. Via Archaeologica Ressoviensia, **7**, FROA, Rzeszów: 221–225.

Gębica, P., Dryniak, Ł., Okoński, J., Zych, R., Hozer, M., Bajda-Wesołowska, A., Wilk, M., Niemasik, D., Pasterkiewicz, W., 2010. Geoarchaeological research on the route of motorway A4. Stratigraphy of layers and changes of environment at the sites in Łąka, Wola Mała, Białobrzegi, Gorliczyna and Ożańsk, podkarpackie voivodship (in Polish with English summary). Materiały i Sprawozdania Rzeszowskiego Ośrodka Archeologicznego, **1**: 79–88.

Jarosz, P., Machnik, J., eds., 2017. Necropolises of the population of the Corded Ware culture from the IIIrd millenium before Chr. in the Szczytna on the Kańczuga Plateau (in Polish with English summary). Via Archaeologica Ressoviensia, **12**, FROA.

Jarosz, P., Machnik, J., Szczepanek, A., eds., 2019. Graves of people of the Corded Ware culture from Mirocin, Przeworsk district (in Polish with English summary). Via Archaeologica Ressoviensia, **15**, FROA.

Jędrzejewska, S., 2019. The south-eastern zone of early slavic settlement in Poland. The state of research on archaeological sources (in Polish with English summary). In: Pogranicza w polskich badaniach mediewistycznych (eds. A. Janeczek, M. Parczewski and M. Dzik): 13–53. Materiały Kongresu Mediewistów Polskich, Rzeszów.

Jędrzejewska, S., Wilk, M., eds., 2015. Multicultural settlement from site 16 in Chłopice, podkarpackie voivodship (in Polish with English summary). Via Archaeologica Ressoviensia **7**, FROA.

Kabała, C., 2019. Chernozem (czarnoziem) – soil of the year 2019 in Poland. Origin, classification and use of chernozems in Poland. Soil Science Annual, **73**: 184–192.

Kabała, C., Przybył, A., Krupski, M., Łabaz, B., Waroszewski, J., 2019. Origin, age and transformation of chernozems in northern Central Europe – new data from Neolithic earthen barrows in SW Poland. Catena, **180**: 83–102. https://doi.org/10.1016/j.catena.2019.04.014

Kalicki, T., 1998. Lithology and stratigraphy of alluvia in the Rada valley (Sandomierz Basin) (in Polish with English summary). In: Genesis, lithology and stratigraphy of Quaternary sediments, IIIrd Seminar. Abstracts of reports and description of posters, 16–17 November, 1998. Wyd. UAM, Poznań: 51–53.

Kalicki, T., Starkel, L., Sala, J., Soja, R., Zernickaya, V.P., 1996. Subboreal palaeochannel system in the Vistula valley near Zabierzów Bocheński (Sandomierz Basin). Geographical Studies IGiPZ PAN, **9**: 129–158.

Klimek, K., Łanczont, M., Nogaj-Chachaj, J., 2006. Historical deforestation as a cause of alluviation in small valleys, subcarpathian loess plateau, Poland. Regional Environmental Change, **6**: 52–61.

Kołodyńska-Gawrysiak, R., 2017. Closed depressions in the loess areas of Poland. Current state of research and prospects for further research (in Polish with English summary). Acta Geographica Lodziensia, **106**: 105–116.

Kołodyńska-Gawrysiak, R., Chodorowski, J., Mroczek, P., Plak, A., Zgłobicki, W., Kiebała, A., Trzciński, J., Standzikowski K., 2017. The impact of natural and anthropogenic processes on the evolution of closed depressions in loess areas. A multi-proxy case study from Nałęczów Plateau, Eastern Poland. Catena, **149**: 1–18. https://doi.org/10.1016/j.catena.2016.07.029

Król D., 2018. Studies on the settlement of the Funnel Baker culture on the loess of Rzeszów Foothills and the Lower San Valley. Materiały i Sprawozdania Rzeszowskiego Ośrodka Archeologicznego, **39**: 39–55. https://doi.org/10.15584/misroa.2018.39.2

Król, D., Niebieszczański, J., 2019. Skołoszów 16 – a spatial arrangement of the Eneolithic settlement of the Funnel Beaker Culture in the Rzeszów Foothills (South-Eastern Poland) in the light of previous excavations and geophysical survey. Interdisciplinaria Archaeologica. Natural Sciences in Archaeology, **10**: 121–128. https://doi.org/0.24916/iansa.2019.22

Kruk, J., 1973. Settlement studies on the Neolithic in the loess uplands (in Polish with English summary). PAN, Instytut Historii Kultury Materialnej.

Lehmkuhl, F., Nett, J.J., Potter, S., Schulte, P., Sprafke, T., Jary, Z., Antoine, P., Wacha, L., Wolf, D., Zerboni, A., Hošek, J., Markovic, S.B., Obreht, I., Sumegi, P., Veres, D., Zeeden, C., Boemke, B., Schaubert, V., Viehweger, J., Hambach, U., 2021. Loess landscapes of Europe – mapping, geomorphology and zonal differentiation. Earth-Science Reviews, **215**: 103496. https://doi.org/0.1016/j.earscirev.2020.103496

Łanczont, M., Wojtanowicz, J., Kulesza, P., Kusiak, J., 2000. Stratygrafia osadów czwartorzędowych w profilu Zarzecze (in Polish). In: Glacjał i peryglacjał na międzyrzeczu Sanu i Dniestru (ed. M. Łanczont): 183–192. Seminarium terenowe, Krasiczyn 4–6 października 2000, Lublin.

Łanczont, M., Nogaj-Chachaj, J., Klimek, K., 2001. The potential of natural environment of the foreCarpathian loess plateau for Neolithic settlement (in Polish with English summary). In: Neolithic and the beginning of Bronze Age in Polish Carpathians (ed. J. Gancarski): 173–199. Muzeum Podkarpackie w Krośnie.

Łanczont, M., Klimek, K., Komar, M., Nogaj-Chachaj, J., Poręba, A., Żogała, B., 2003. Non invasion search of the burial mound. As an example of mound No 2 on the site 37 in the Cieszacin Wielki (in Polish with English summary). Rocznik Przemyski, **39**: 5–17.

Łanczont, M., Nogaj-Chachaj, J., Klimek, K., 2006a. Research on the geomorphological effects of Early Medieval settlement in the Kańczuga Plateau (Foreland of the Carpathians) (in Polish with English summary). In: Early Medieval in the Polish Carpathians (ed. J. Gancarski): 338–354. Muzeum Podkarpackie w Krośnie.

Łanczont, M., Nogaj-Chachaj, J., Komar, M., Kusiak, J., Zernickaya, W., 2006b. Difficulties with palaeogeographical and stratigraphic interpretation of slope deposits and underlying paleopedon, and their archaeological context (a case study from Cieszacin Wielki, Kańczuga Plateau, SE Poland) (in Polish with English summary). Rocznik Przemyski, **62**: 3–21.

Machnik, J., 2011. Importance of archaeological rescue research along the planned route of the A4 motorway construction in the section Przeworsk-Radymno to widen the knowledge concerning the issues of the late Neolithic period and the early Bronze Age (in Polish with English summary). In: Motorway to the past. Exhibition catalogue (ed. S. Czopek): 61–77. Muzeum Okręgowe w Rzeszowie.

Malata, T., 1999. Budowa geologiczna wysoczyzny lessowej na zachód od Jarosławia (in Polish). The materials of 4th Conference of the stratigraphy of Pleistocene of Poland, Czudec 31 VIII–4 IX 1999: 43–47.

Malicki, A., 1973. Jednostki fizjograficzne dorzecza górnego Sanu (in Polish). In: Natural environment of the San River basin, its economic importance and protection. The materials from science conference, 16–17th October 1970, Przemyśl. Biblioteka Przemyska, **6**, TPN: 9–35.

Maruszczak, H., 1991. General features of loesses in Poland (in Polish with English summary). In: Main sections of loesses in Poland (ed. H. Maruszczak): 1–12. Wyd. UMCS, Lublin.

Marks, L., 2023. Quaternary stratigraphy of Poland – current status. Acta Geologica Polonica, **73**: 307–340. https://doi.org/10.24425/agp.2023.145614

Mazurek, M., Sznajdrowska, A., 2016. Site 24, 25 i 27 in Mirocin, Commune Przeworsk. Part I. Late Polgarian settlements and Funnel Baker cultures (in Polish with English summary). Via Archaeologica Ressoviensia, FROA **11**: 1–115.

Michno, A., 2012. Age and lithological diversity of floor sediments in the Lower Nidzica valley in the Małopolska Upland (Southern Poland). Zeitschrift für Geomorphologie, **57**: 111–135. https://doi.org/10.1127/0372-8854/2012/009

Mocek, A. ed., 2015. Gleboznawstwo (in Polish). PWN, Warszawa.

Moska, P., Bluszcz, A., Poręba, G., Tudyka, K., Adamiec, G., Szymak, A., Przybyła, A., 2021. Luminescence dating procedures at the Gliwice Luminescence Dating Laboratory. Geochronometria, **48**: 1–15. https://doi.org/10.2478/geochr-2021-0001.

Nogaj-Chachaj, J., Klimek, K., Łanczont, M., 2005. Primaeval settlement eastern part of Sandomierz Basin in aspect of development of the San valley bottom. In: Archaeology of Sandomierz Basin (ed. M. Kuraś) (in Polish with English summary). Rocznik Muzeum Regionalnego w Stalowej Woli, **4**: 57–76.

Parczewski, M., 1986. Stand der Forschung über den karpatischen Teil des San-Einzugsgebiets im Frühmittelalter (6.–12. Jh.). In: Urzeitliche und frühhistorische Besiedlung der Ostslowakei in Bezug zu den Nachbargebieten. Archeologicky Ustav SAV, Nitra: 285–295.

Parczewski, M., 2011. Early Slavonic settlement (5/6th–7th AD) on the route of Motorway A4 in the south-eastern Poland (in Polish with English summary). In: Motorway to the Past. Exhibition Catalogue (ed. S. Czopek): 97–108. Muzeum Okręgowe w Rzeszowie.

Pelisiak, A., 2018. Centre and periphery of settlement in the Neolithic and early Bronze Age in eastern SubCarpathian (Podkarpacie) and in the eastern part of the Polish Carpathians (in Polish with English summary). Uniwersytet Rzeszowski.

Przybyła, M., Blajer, W., 2008. Settlement structures in the Bronze Age and early Iron Age on the area of the foreCarpathian loess plateau between the Wisłok and San (in Polish with English summary). Wyd. Uniwersytetu Jagiellońskiego, Kraków.

Reimer, P.J., Austin, W., Bard, E., Bay-liss, A., Blackwell, P.G., Bronk Ramsey, C., Butzin, M., Cheng, H., Edwards, R.L., Friedrich, M., Grootes, P.M., Guilderson, T.P., Hajdas, I., Heaton, T.J., Hogg, A.G., Hughen, K.A., Kromer, B., Manning, S.W., Muscheler, R., Palmer, J.G., Pearson, C., Van Der Plicht, J., Reimer, R.W., Richards, D.A., Scott, E.M., Southon, J.R., Turney, C.S.M., Wacker, L., Adolphi, F., Büntgen, U., Capano, M., Fahrni, S.M., Fogtmann-Schulz, A., Friedrich, R., Köhler, P., Kudsk, S., Miyake, F., Olsen, J., Reinig, F., Sakamoto, M., Sookdeo, A., Talamo, S., 2020. The IntCal20 northern hemisphere radiocarbon age calibration curve (0–55 cal kBP). Radiocarbon, **62**: 725–757. https://doi.org/10.1017/RDC.2020.41

Rejman, J., Rafalska-Przysucha, A., Rodzik, J., 2014. The effect of land use change on transformation of relief and modification of soils in undulating loess areas of east Poland. The Scientific World Journal, **2014**: 1–11. https://doi.org/10.1155/2014/341804

Rodzik, J., Mroczek, P., Wiśniewski, T., 2014. Pedological analysis as a key for reconstruction of primary loess relief – a case study from Magdalenian site in Klementowice (eastern Poland). Catena, **117**: 50–59. https://doi.org/10.1016/j.catena.2013.09.001

Rodzik, J., **Niezabitowska-Wiśniewska, B., Nitychoruk, J., Budziszewski, J., Jakubczak, M., 2017**. Geological and geomorphological conditions and traces of prehistoric and historic human settlements in the vicinity of Ulów (Roztocze Region, Southeastern Poland). Studia Quaternaria, **34**: 83–97.

Rybicka, M., 2011. The Funnel Baker Culture in the foreCarpathian loess. Commentary on the "Motorway" research (in Polish with English summary). In: Motorway to the Past. Exhibition Catalogue (ed. S. Czopek): 45–59. Muzeum Okręgowe w Rzeszowie.

Skiba, S., Drewnik, M., 2003. Map of soils of the area of Carpathians in Polish borders (in Polish with English summary). Roczniki Bieszczadzkie, **11**: 15–20.

Skiba, S., Kołodziejczyk, M., 2004. Genesis and taxonomy of Polish chernozem in the light of archaeological research in Słonowice (in Polish with English summary). In: Geographical Environment Changes in the Period of Farming and Breeding Economy. Studies from Poland's area (eds. D. Abłamowicz and Z. Śnieszko): 87–98. Muzeum Śląskie w Katowicach.

Skiba, S., Szymański, W., 2009. The soils of Carpathians and their role in the development of the Neolithic agriculture (in Polish with English summary). In: The Natural Resources and Their Used in Prehistoric and Early Medieval Periods (ed. J. Gancarski): 325–340. Muzeum Podkarpackie w Krośnie.

Solon, J., Borzyszkowski, J., Bidłasik, M., Richling, A., Badora, K., Balon, J., Brzezińska-Wójcik, T., Chabudziński, Ł., Dobrowolski, R., Grzegorczyk, I., Jodłowski, M., Kistowski, M., Kot, R., Kraż, P., Lechnio, J., Macias, A., Majchrowska, A., Malinowska, E., Migoń, P., Myga-Piątek, U., Nita, J., Papińska, E., Rodzik, J., Strzyż, M., Terpiłowski, S., Ziaja, W., 2018. Physico-geographical mesoregions of Poland: verification and adjustment of boundaries on the basis of contemporary spatial data. Geographia Polonica, **91**: 143–170. https://doi.org/110.7163/GPol.0115

Starkel, L., 1996. Geomorphic role of extreme rainfalls in the Polish Carpathians. Studia Geomorphologica Carpatho-Balcanica, **30**: 21–38.

Starkel, L., 2005a. Anthropogenic soil erosion since the Neolithic time in Poland. Zeitschrift für Geomorphologie, Suppl., **139**: 189–201.

Starkel, L., 2005b. Relief types of the Sandomierz Basin and their role in the formation of prehistoric settlement (in Polish with English summary). Rocznik Muzeum Regionalnego w Stalowej Woli, **4**: 11–17.

Starkel, L., Czopek, S., Madeja, J., Budek, A., Harmata, K., 2002. Evolution of the environment and settlement on the foreland of the margin of the Carpathians in the environs of Sędziszów and Rzeszów (in Polish with English summary). Materiały i Sprawozdania Rzeszowskiego Ośrodka Archeologicznego, **23**: 5–30.

Śnieszko, Z., 1995. Evolution of loess areas of the Polish Uplands during the last 15 000 years (in Polish with English summary). Wydawnictwa Uniwersytetu Śląskiego, Katowice.

Szwarczewski, P., 2009. The formation of slopewash (deluvial) and alluvial cones as a consequences of human settlement on the loess plateau: An example from the Chroberz area (Poland). Radiocarbon, **51**: 445–455. https://doi.org/10.1017/S0033822200055843

Twardy, J., Kamiński, J., Moszczyński, J., 2004. Records of man's economic activity and settlement in the La Tiene and Roman periods in landforms and deposits of Middle Poland (in Polish with English summary). In: Geographical Environment Changes in the Period of Farming and Breeding Economy. Studies from Poland's Area (eds. D. Abłamowicz and Z. Śnieszko): 197–221. Muzeum Śląskie w Katowicach

Vysloužilova, B., Dankova, L., Ertlen, D., Novak, J., Schwartz, D., Sefrna, L., Delhon, C., Berger, J.F., 2014. Vegetation history of chernozems in the Czech Republik**.** Vegetation History and Archaeobotany, **23**: 97–108. https://doi.org/10.1007/s00334-014-0441-7

Wilk, M., Kadrow, S., Szperkowska, K., Cygan, S., Kubicka-Marek, A., 2013. Opracowanie wyników ratowniczych badań archeologicznych na stanowisku Ożańsk 13 (in Polish). Archiwum FROA.

Zygmunt, E., 2004. Archaeological and radiocarbon dating of alluvial fans as an indicator of prehistoric colonisation of the Głubczyce Plateau (southwestern Poland). Geochronometria, **23**: 101–107.