Geological Quarterly, 2023, 67: 32
DOI: http://dx.doi.org/10.7306/gq.1702

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

Inside and outside a burial mound: when, how and in what environment were the kurgans built by Late Neolithic communities on the Subcarpathian loess plateau (SE Poland)?

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Łanczont, M., Nogaj-Chachaj, J., Żogała, B., Komar, M., 2023. Inside and outside a burial mound: when, how and in what environment were the kurgans built by Late Neolithic communities on the Subcarpathian loess plateau (SE Poland)? Geological Quarterly, 67: 32; https://doi.org/10.7306/gq.1702

The unique, well-preserved kurgan complex near Cieszacin Wielki (SE Poland) is a specific type of archaeological site with its own landscape form. This complex of prehistoric earth burial mounds, located on a wide, flat watershed hilltop with NW–SE orientation, belongs to a chain of similar forms found in the loess foreland of the Carpathians. The kurgans were probably built by Late Neolithic communities of the Corded Ware culture engaged in pastoralism with rotational grazing. Taking into account the need to preserve this valuable element of the cultural landscape and archaeological heritage in its original form, instead of by excavation that would irretrievably destroy the site, non-invasive and minimally invasive investigations were carried out at the Cieszacin Wielki site. The results of lithological, geochemical, palaeopedological and palynological analyses as well as combined geophysical prospection were used to examine the structure of the kurgans, and to reconstruct their original appearance and the natural palaeoenvironment in their surroundings. The time when the mounds were built was determined based on radiocarbon dating of organic material in the samples taken from boreholes made into them. The kurgans near Cieszacin Wielki are of different sizes and occur close to each other. The cover of the mounds consists of two layers. An inner dark layer contains humus material evidently indicating earlier human activity due to a high content of phosphorus. Radiocarbon dating shows that the material of this layer was formed about 4800–5300 cal BP, so it is a remnant of the Funnel Beaker cultural layer. Pollen analysis indicates that each mound was decorated with blooming birch twigs after the first stage of kurgan construction. This practice could have been an expression of magic and ritual ceremonies as well as being aimed at protecting the mound from erosion. Grooves around the circumference of the mounds marked their original extent. Subsequently, the whole mound was covered with pale loess material taken from a nearby pit. Geophysical investigations indicated the existence of several anomalies, differing in size and shape, inside the mounds. These represent burial chambers located at various depths both under and within each mound. Based on pollen analysis, we think that the kurgans were originally located not in open landscape but in a mid-forest clearing, in an area previously used by the people of the Funnel Beaker culture, probably for cattle grazing.

Key words: llithological method, combined geophysical approaches, pollen analysis, stratigraphy, environmental history, Corded Ware culture, Holocene.

INTRODUCTION

A kurgan is a specific form of archaeological site with its own landform (Kobyliński, 1999, 2019), at the same time being a kind of time capsule in which a specific section of the geographical environment history is recorded. It may have varied in form and size but usually it was an earth mound, built on a circular or near-circular plan, most commonly over a burial (grave). In SE Poland, kurgans in different states of preservation are found mainly in the Sokal Plateau-Ridge, Roztocze, Kańczuga Plateau, Dynów Foothills and Strzyżów Foothills regions. They occur also in the Ukrainian Eastern Subcarpathians, as far as the valleys of the Bystrytsia and Zolota Lypa rivers in the southerneast (Demetrykiewicz, 1897; Sulimirski, 1968; Gedl, 1995, 1997, 2001; Czopek, 1997, 1999; Makarowicz et al., 2017; Machnik, 1998, 2011; Machnik et al., 2019).

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Received: May 15, 2023; accepted: June 23, 2023; first published online: December 14, 2023

People of different archaeological cultures in different areas and at different times built earth mounds in order to mark burial sites. These were located on exposed and clearly visible hilltops, which were naturally defensive and of strategic importance to the construction of the settlement and road network of a given community of a specific culture. Besides their funeral function, these new permanent elements of the landscape were also observation points, landmarks and possessed symbolic importance. It is generally (traditionally) assumed that such mounds were built by communities leading a nomadic and semi-nomadic life, probably pastoral (Kruk and Milisauskas, 1999; Włodarczak, 2011).

In the Kańczuga Plateau and Dynów Foothills, all burial mounds excavated so far are unambiguously related to the Corded Ware culture. So far, no traces of camps and settlements of this culture have been identified in these areas. The only information about of such settlement was obtained during the excavations of the archaeological site in Side near Sambir in the Eastern Subcarpathians (Machnik et al., 1997). Culturally related groups practiced some form of rotational grazing (Machnik et al., 2019), which probably consisted of change of grazing places within a specific region with similar ecological conditions. For the Kańczuga Plateau, it was probably the Sokal Plateau-Ridge, the western part of Eastern Roztocze, and the loess uplands of the San and Dnister interfluve (Machnik, 2019; Machnik et al., 2019). More frequent seasonal rotation may have been limited to a specific area of this zone. Groups of people from more distant areas also reached the plateau, perhaps only once, and not all for the same purpose (Kruk and Milisauskas, 1999).

Archaeological investigations indicate that the Subcarpathian loess upland areas used as pastures by the people of the Corded Ware culture were the same as those that were earlier settled by Neolithic agricultural communities practicing slash-and-burn cultivation and deforestation, which could have led to a locally significant transformation of the natural environment (Kruk and Milisauskas, 1999; Machnik et al., 2000; Kadrow and Zakościelna, 2000; Łanczont and Wojtanowicz, 2006). In such areas, the people of the Corded Ware culture found favourable environmental conditions for a pastoral economy (Demetrykiewicz 1897; Sulimirski, 1968; Machnik, 1995; Machnik and Sosnowska, 1996, 1998; Machnik, 1998).

Well-preserved kurgans are relatively rare today in both SE Poland and the Ukrainian Eastern Subcarpathians. Many of them have been irretrievably destroyed due to intensive human economic activities, others as a result of natural erosion and denudation processes. In agricultural areas, their remnants occur either as artefacts modified by ploughing, or – in the best case – as darker flat patches against a lighter background of the subsoil (Lach, 1984; Machnik, 1995). Relatively well-preserved earth mounds are more often found within forest areas (Czopek, 1997; Gedl, 1997).

PURPOSE OF RESEARCH

Observations and minimally invasive research methods were used to investigate a complex of 4 kurgans (Figs. 1C and 2A) occurring in the archaeological sites with identification numbers 37/129 (Kostek and Paradyło, 2000) and 38/136 (Łanczont et al., 2001a). The complex is located south of the city of Jarosław, on the eastern side of the A4 motorway, near Cieszacin Wielki. The kurgans are exceptionally well preserved. Nowadays, such objects are valued as elements of the cultural landscape and of archaeological heritage. The few preserved prehistoric mounds are strictly protected, allowing further investigation of their function and chronology using natural science methods. The results of such research constitute an independent source of information that can be compared with materials excavated from other burial sites in the region.

The kurgans near Cieszacin Wielki were analysed using non-invasive geodetic and geophysical survey as well as minimally invasive geological investigations (boreholes). The samples collected were analysed using different methodologies. The results obtained have so far been published as separate reports, mainly in Polish. Here we combine and interpret all the results to provide a new assessment of the history of the kurgans and of the surrounding natural environment and cultural landscape, and to constrain when the burial mounds were built.

STUDY AREA

The kurgans investigated are located in the central part of the Kańczuga Plateau situated in the south-eastern part of the Sandomierz Basin (Starkel, 1972). Due to the occurrence of continuous loess cover, this area is called the foremountain Carpathian loess region (Maruszczak, 1991; Fig. 1A, B). The loess cover, mainly from the last glaciation, is from a few to ten or more metres thick (Laskowska-Wysoczańska, 1971). The geographical axis of the region is the Mleczka River. Its eastern tributary, the Mleczka Wschodnia River, is fed by numerous small streams (Fig. 1B). This river system, together with a network of dry erosion-denudation valleys, contributed to a strong dissection of the area and the formation of narrow, elongated hills. Their flat surfaces occur on three levels with heights of 255–265, 235–245 and 225–230 m a.s.l. (Fig. 2B). The Mleczka Zarzecka is a small stream, which flows into the Mleczka Wschodnia River to the south of Cieszacin Wielki (Fig. 2B). In the upper part of the valley (Fig. 1C), its wide, boggy and poorly drained bottom (of physiographic name Old Swamps) is filled with a 5–10 m-thick succession of Holocene peaty silts, very clayey peats and loess deluvia (Łanczont et al., 2001b, 2004a; Łanczont and Nogaj-Chachaj, 2003).

The present-day soil cover of the Mleczka Zarzecka stream catchment is characterized by a mosaic pattern clearly dependent on the relief (Fig. 3A, B). The soil cover of the slopes and tops of the hills consists mainly of brown and leached brown soils. Chernozems occupying a slightly smaller area form patches of various sizes or are dispersed. All depressions are filled with soils classified as deluvial chernozems, and their pattern follows the arrangement of bottoms of trough-like small valleys.

KURGANS NEAR CIESZACIN WIELKI

The complex of kurgans occurs on a wide, flat watershed hilltop oriented NW–SE and with a height of 256–261 m a.s.l., which closes the Old Swamps wilderness from the northeast (Figs. 1C and 2B). Three mounds (site 37/129) occur close to each other forming a characteristic burial mound field. They form an obtuse triangle in plan view on a relatively flat southern part of the hill (258 m a.s.l.) The fourth kurgan (site 38/136) is located ~300 m to the NW of this complex, on the culmination (261 m a.s.l.) of a narrow western extension of the hill. A further, previously unknown, kurgan of similar size and shape occurs 300 m to the east (Fig. 2B). The archaeological sites are overgrown with 40- and 50-year-old trees.

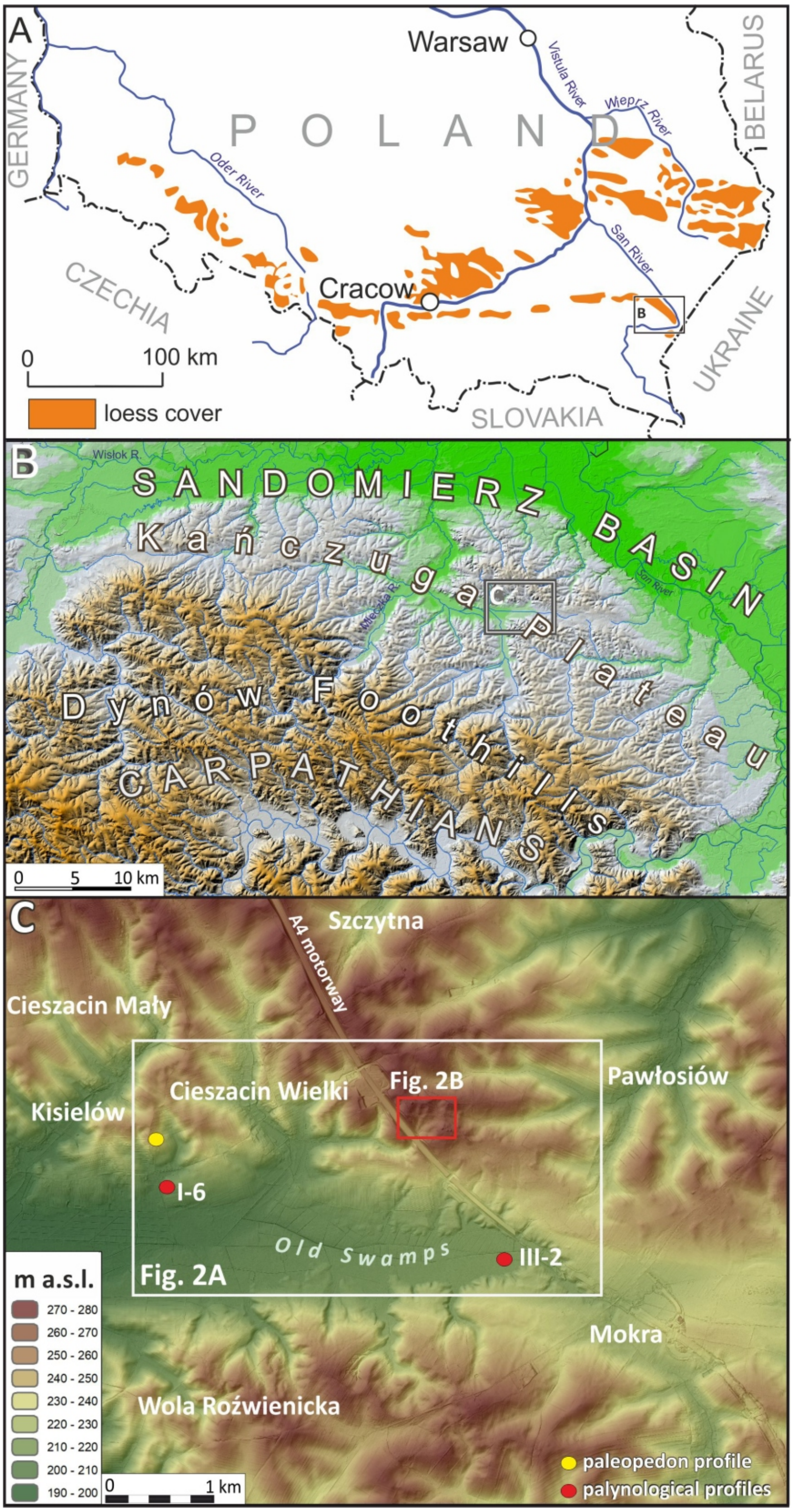

Fig. 1. Situation of the study area on the background of:

A – loess map of S Poland (Maruszczak, 1991); **B** – relief model of SE Poland as prepared by L. Gawrysiak; **C** – relief model of the Cieszacin Wielki area, based on the LiDAR data, GUGiK; the study area is marked by a red rectangle

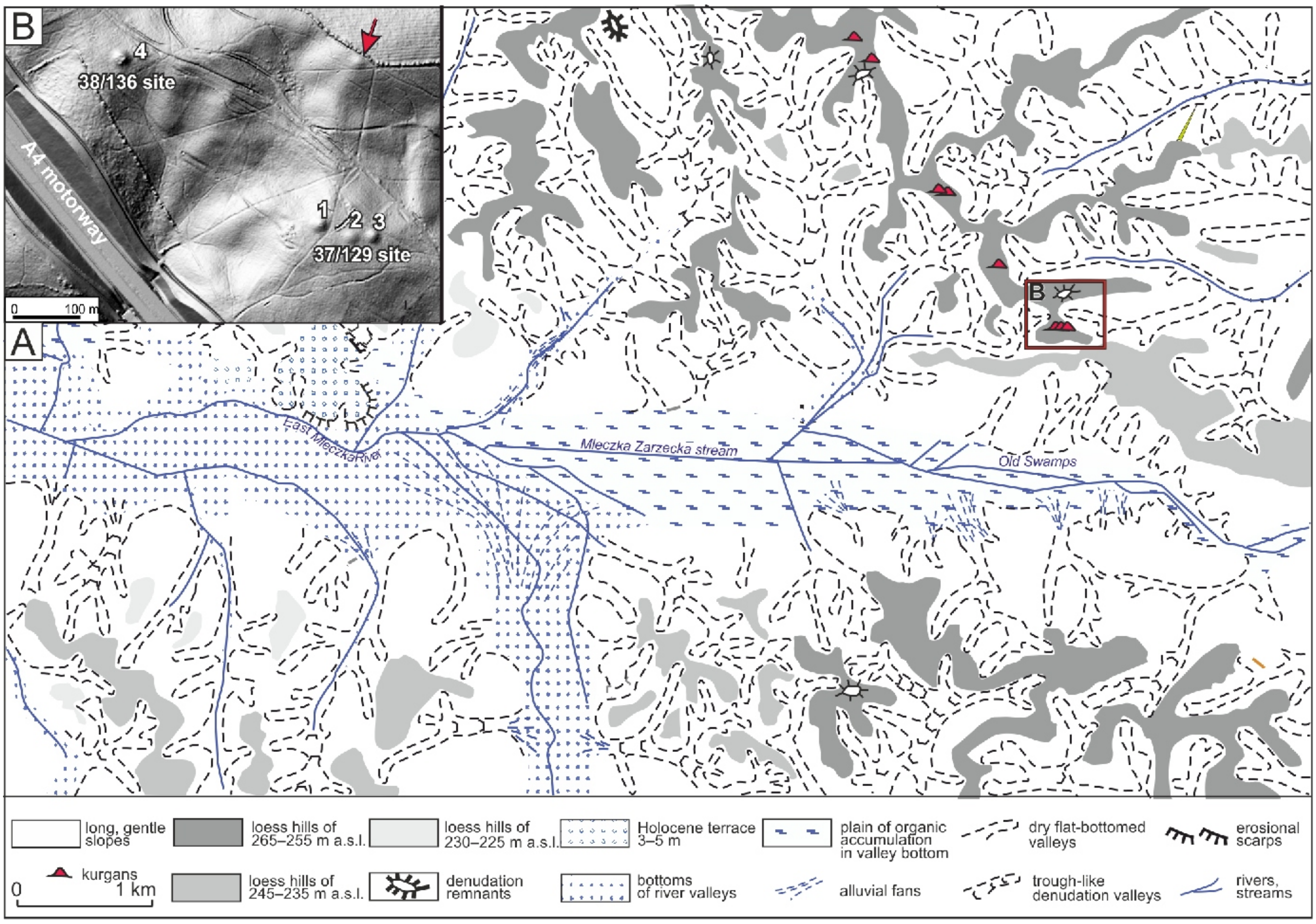

Fig. 2A – geomorphological sketch of the Cieszacin Wielki surroundings according to Łanczont et al. (2001, modified); B – relief model of the kurgan complex studied near Cieszacin Wielki (archaeological sites 38/136 and 37/129) based on the LiDAR data (GUGiK)

MATERIALS AND METHODS

The research included field geodetic, geological and geophysical investigations as well as laboratory analyses. These aimed at developing a relief model of kurgans, determining the stratigraphy and chronology (based on radiocarbon dating) of the mound layers, and describing the properties of the soil underlying and surrounding the kurgans to provide local palaeoecological context against a wider background of vegetational changes in the Holocene.

FIELDWORK

A geodetic survey of the kurgans at site 37/129 (which were given successive numbers 1–3), and at site 38/136 (number 4) resulted in detailed height maps. A geophysical survey was carried out at both sites and non-invasive geological investigations were conducted at site 37.

Geological investigations. To examine the internal structure of three kurgans as well as of the soil underlying them and the present-day soil in their immediate vicinity, 25 boreholes were drilled (using a hand corer with 5 cm diameter) along an E–W section (kurgan 1), and a N–S section (kurgan 2), with one borehole drilled into the top of kurgan 3. The distances between the boreholes depended on the size and shape of the mound, as well as on the present-day position of trees and roots.

Geophysical methods. For archaeological reasons, the geophysical research focused on the shallowest layers, to a depth of several metres. Initially focus was on locating and contouring local anomalies which may be linked with shallow-lying anthropogenic objects (Goodman, 1994; Griffiths and Barker, 1994; Misiewicz, 1998; Żogała, 2013; Magiera et al., 2019, 2020). The continuous electromagnetic - conductive profiling method was used, using an *EM31-MK2* conductivity meter made by *Geonics*. In this, an electromagnetic field is generated by a transmitting coil during measurement. This field propagates through the ground, which causes the formation of eddy currents in conductive parts of the geological deposits. There currents generate a secondary field registered by the receiving coil as an apparent electrical conductivity of the subsurface (in mS/m). The measurements were made along traverses, automatically programmed to record a reading every 0.5 s, while the vertical coil orientation allowed values of the apparent electrical conductivity to be obtained every ~0.3 m and to a depth of ~6 m below ground level. Parallel measurement profiles were marked out every 1.0 m and extended beyond the mound zone. It provided detailed information on changes in the electrical conductivity of the nearby area. The measurements were made on the kurgans 1, 2 and 3 and the results are shown as maps of the changes in apparent electrical conductivity.

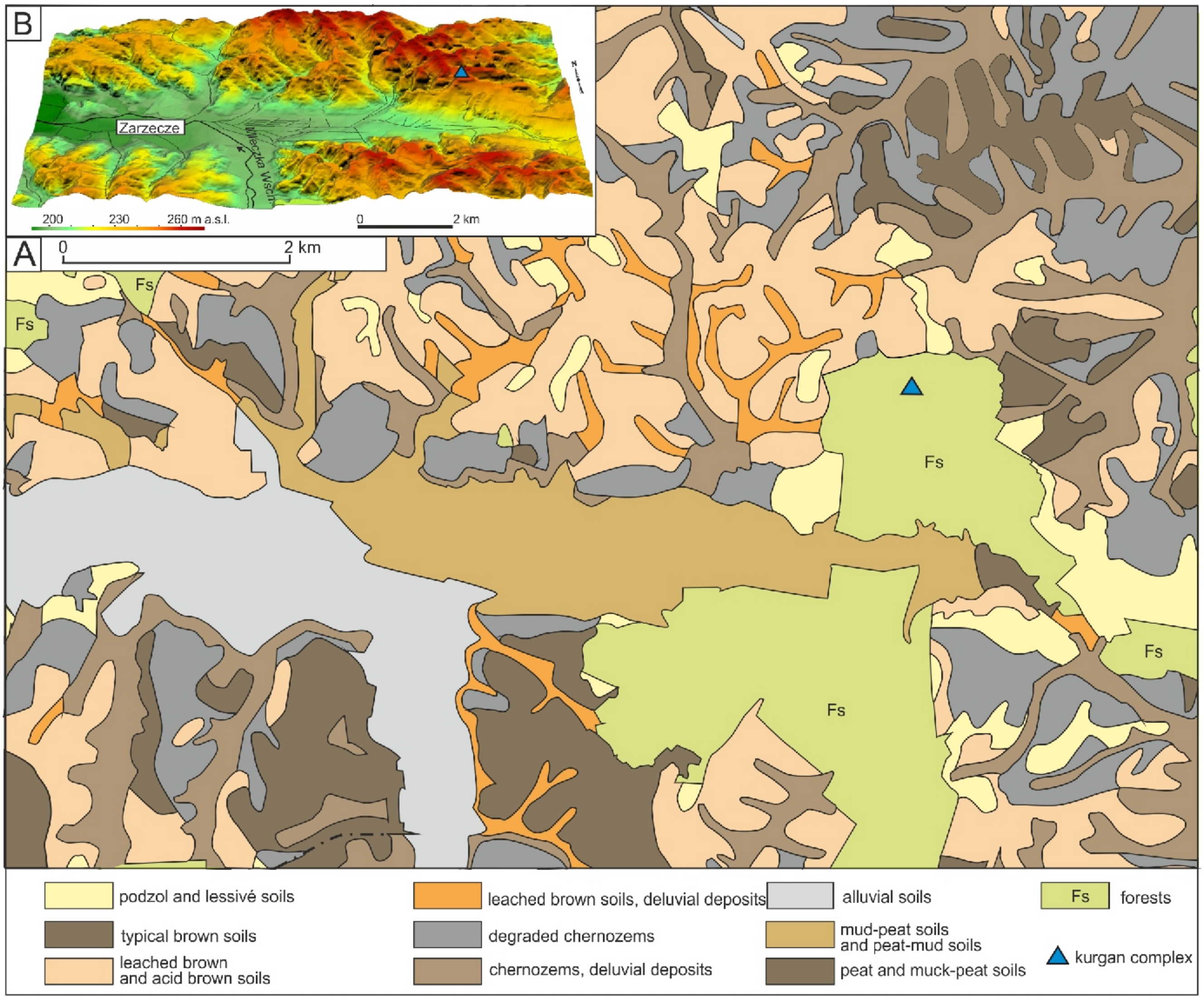

Fig. 3. The study area on the background of map of the soil cover of the Cieszacin Wielki surroundings, according to Łanczont et al. (2001, modified) (A) and relief model of the Mleczka Zarzecka Stream valley area (B)

The subsequent focus was on a detailed analysis of anomalies found. The electrical resistivity imaging method was used (RI), measurements were taken using the Lund Imaging system by ABEM. It allowed the determination of the distribution of resistivity in the geological deposits along the measurement profiles up to a certain depth dependent on the length of full electrode spacing. The value measured in the field is apparent electrical resistivity. Measurements were taken all along the profile using a temporary set measurement system in the current electrode sequence, the sequence changing automatically until all programmed sequences are used. Inversion of the values obtained, including the topography, was carried out using *Res2D by Geotomo Software*. On resistivity cross-sections so obtained in the XY plane the location of all interesting anomalies may be determined (Łanczont et al., 2003, 2004b; Poręba et al., 2003, 2007; Poręba, 2006, 2007). Measurement on kurgan 1 was along one profile and on kurgan 2 along 8 profiles. Such a concentration of profiles is rare in practice, but can help constrain the spatial variability of the anomalies discovered.

LABORATORY ANALYSES

The small amount of core material obtained was insufficient to carried out all laboratory analyses as listed below on the same samples.

Grain size distribution and geochemical analyses. Grain size distribution was determined by areometric method on representative samples taken from layers identified in five selected profiles along kurgans 1 and 2. Based on the grain size distribution, selected granulometric indices were calculated following Folk and Ward (1957): average grain size, sorting, skewness and kurtosis. The contents of humus (Tiurin method), calcium carbonate (volumetric method using the Scheibler apparatus) and iron oxides (thiocyanate colorimetric method) were determined in the deposits of kurgan 2. These analyses were carried out in the laboratory of the Institute of Earth and Environmental Sciences of the Maria Curie-Skłodowska University in Lublin. Initial results were provided by Łanczont et al. (2003, 2004b).

In the geochemical laboratory of the Faculty of Earth Sciences of the University of Silesia in Sosnowiec, 25 samples from boreholes (nos. 1, 4, 8) drilled into kurgan 1 were analysed. The samples were digested in a mixture of acids (H_2SO_4, HF, HNO_3), then the contents of the main components (K_2O, Na_2O, CaO, MgO, Fe_2O_3, MnO) and selected trace elements (Ba, Sr, Zn, Pb, Cu) were determined by atomic absorption spectrometry (AAS) using a *Unicam Solaar M6* spectrometer. Additionally, the samples were calcined to a constant weight at 450°C, and then digested using the acids listed above. In the solution obtained the phosphorus content was determined by spectrophotometry (using a vanadium-molybdenum reagent, and measuring the absorbance of a coloured phosphorus complex compound at a wavelength of 430 nm). In addition, the mineral composition of 17 samples was determined using a *Philips PW 3710* X-ray diffractometer. Initial results are discussed in Łanczont et al. (2007).

Pollen analysis. In order to determine the natural environmental conditions when the kurgans were built, 22 samples for pollen analysis were taken: (i) from the dark (humic) layer of kurgan 1 (profile 3); (ii) from the soil underlying the kurgan (profile 2); (iii) from the present-day soil near the kurgan as contextual material (profile 6).

Samples were taken every 10 cm; each sample was 5 cm thick. This material was boiled in 15% $Na_4P_2O_7$, and then subjected to flotation in heavy liquid (a solution of cadmium iodide and potassium iodide). The remaining finer mineral fraction was removed using 40% hydrofluoric acid and 10% hydrochloric acid. The organic material separated was subjected to acetolysis. Details of analytical procedure are in Komar and Łanczont (2002) and Komar et al. (2003). The analysis also took into account the conditions of preservation of the pollen in the loess deposits. The results obtained are shown as histograms. The percentages of individual taxa are calculated based on the sum of AP, NAP and P, where AP denotes trees and shrubs, NAP being dwarf shrubs and terrestrial herbs, and P being sporomorphs. Pollen of *varia* and redeposited palynomorphs are excluded from the basic sum but their percentages are also calculated in relation to this sum.

The pollen analysis results were discussed in context of the Late Glacial and Holocene transformations of the environment that were reconstructed based on the investigations of mineral and organic deposits occurring in two topographic positions (Fig. 1B), i.e. on the northern slope of the Mleczka Zarzecka Stream valley (a Late Glacial succession of two palaeosols) and in its bottom (valley-fill deposits). These results were published by Alexandrowicz et al. (2003), Zernickaya et al. (2003), Komar et al. (2003) and Łanczont et al. (2004a).

Dating of deposits in kurgans and other sites. Five samples of material taken from the interior of mounds 1 (two samples) and 2 (three samples) were radiocarbon dated in the laboratory of ING NAN in Kyiv, Ukraine (Łanczont et al., 2004a). The dates obtained were calibrated using the *IntCal 20* calibration curve (Reimer et al., 2020) in *OxCal v4.4.4* (Bronk Ramsey, 2009, 2021).

Additionally, other results of radiocarbon dating were used in the study, i.e. those obtained in the same laboratory for the organic materials taken from core samples taken in the Old Swamps wilderness. Based on these, the time spans of the formation of the valley-fill deposits and the phases of anthropopressure were determined (Zernickaya et al., 2003; Łanczont et al., 2004a). We also considered the results of TL dating of the mineral substrate of the organic material as well as of the palaeosol found on the slope of this catchment. These ages were obtained in the luminescence laboratory of the Institute of Earth and Environmental Sciences of the Maria Curie-Skłodowska University in Lublin (Łanczont et al., 2004). Details of this method are in Fedorowicz et al. (2013).

RESULTS

MORPHOMETRY AND INTERNAL STRUCTURE OF THE KURGANS

Three kurgans at site 37/129 are generally cone-shaped, built on a circular plan with a diameter of 24 m (kurgan 1) and 16 m (kurgan 3) or an elliptical plan with axes 28 and 26 m long (kurgan 2; Fig. 4). Clearly visible depressions in the top parts of kurgans 1 and 2, and on the southern slopes of the former, may be the traces of old excavations or holes left by uprooted trees. Kurgan 4 at site 38/136 has an ellipsoidal plan (25 x 30 m) and also a concave top (Fig. 4). The present-day height of the kurgans varies from 1.2 to 3.5 m, probably lower than originally.

STRUCTURE, LITHOLOGY AND CHEMICAL COMPOSITION OF KURGANS 1–3

No bone and ceramic material were found while drilling into kurgans 1–3. This may be due to chance or to non-preservation of the remains. The boreholes unambiguously indicate that the structure of each mound is not uniform (Fig. 5). The mound cover is bipartite and consists of two continuous layers differing in their colour (light, dark), lithology (silty, clayey), and compactness (loose, compact) of the material. Below these, in the central part of each mound, there is a spatially restricted and probably discontinuous lens of multicoloured, very clayey material, considered to be the infill of a burial chamber (Łanczont et al., 2003). As each kurgan is artificial, the main lithological and geochemical features of the layers distinguished reflect the characteristics of the material taken by humans to form them. These features have been modified in the near-surface part of the mound by present-day pedogenesis and/or human activities. Pedogenetic changes older than the kurgan are present in the soil buried beneath it (Figs. 6–8).

In the deposits of kurgans 1 and 2 the average grain size (Mz) value is 7 , sorting is poor ($_1$ = 1–1.5), grain size distribution very positively skewed (Sk_1 = 0.3–0.5) and leptokurtic (K_G = 1–1.5). These indices are typical of poorly sorted deposits, which in natural conditions are represented, for example, by mass transport deluvial sediments. The kurgan deposits are carbonate-free and of variable humus content: the highest (>4%) in the soil near the mound surfaces, and lower (1–2%) in the dark layer, with the lowest (<0.5%) in the supposed burial chamber (Fig. 7). All samples taken from kurgan 1 and its substrate are of similar mineral composition (Łanczont et al., 2007). Quartz predominates, while other components such as potassium and sodium feldspars, phyllosilicates (illite, kaolinite, smectite and chlorite) and carbonates (calcite and dolomite) are less important, constituting from several to ten or so percent. The individual chemical elements show similar distributions in the drilling profiles (Fig. 6). The average contents of the elements analysed are as follows: Mn – 427 ppm, Ba – 318 ppm, Sr – 60 ppm, Cu – 10 ppm, Zn – 29 ppm and Pb – 11 ppm. The similarity within samples of CaO and Sr contents indicates that strontium is completely bound within carbonates. The pattern of barium indicates the sorption of this element onto hydrous manganese oxides and its occurrence in the structure of carbonates in the layers representing the carbonate loess of the kurgan substrate. The Zn content shows clear correlation with the iron, phosphorus and manganese contents. The mean total iron content, converted into Fe_2O_3, is 2.21% in the samples taken from the mound. Iron occurs in the structures of phyllosilicates (illite, chlorite, smectite) and also, in very low amounts, in the form of phosphate. The values of loss on ignition at 450°C, which approximately correspond to the content of organic carbon, vary from 1.12 to 7.98%). The phosphorus (P) content varies from 297 ppm to 559 ppm, with an average value of 434 ppm (Łanczont et al., 2007).

Outer light layer of the kurgan cover. The light layer (Fig. 5 – layer a) with a variable thickness of 0.3–0.5 m, is slightly yellowish. It is composed of material with appearance and properties similar to loess; it contains 35% silt, >9% clay, 5–6% sand, and 1.1–1.4% iron compounds (Figs. 6 and 7). The

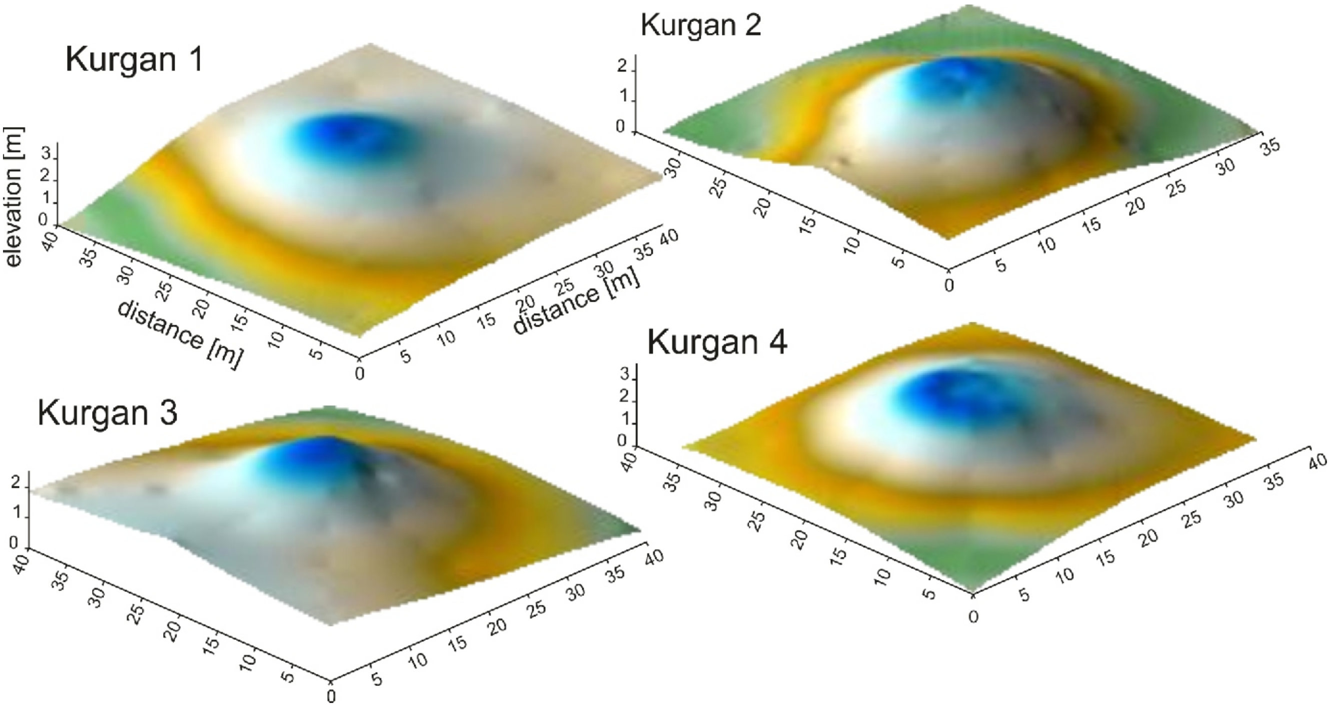

Fig. 4. Topographic 3D model of the kurgans 1–4

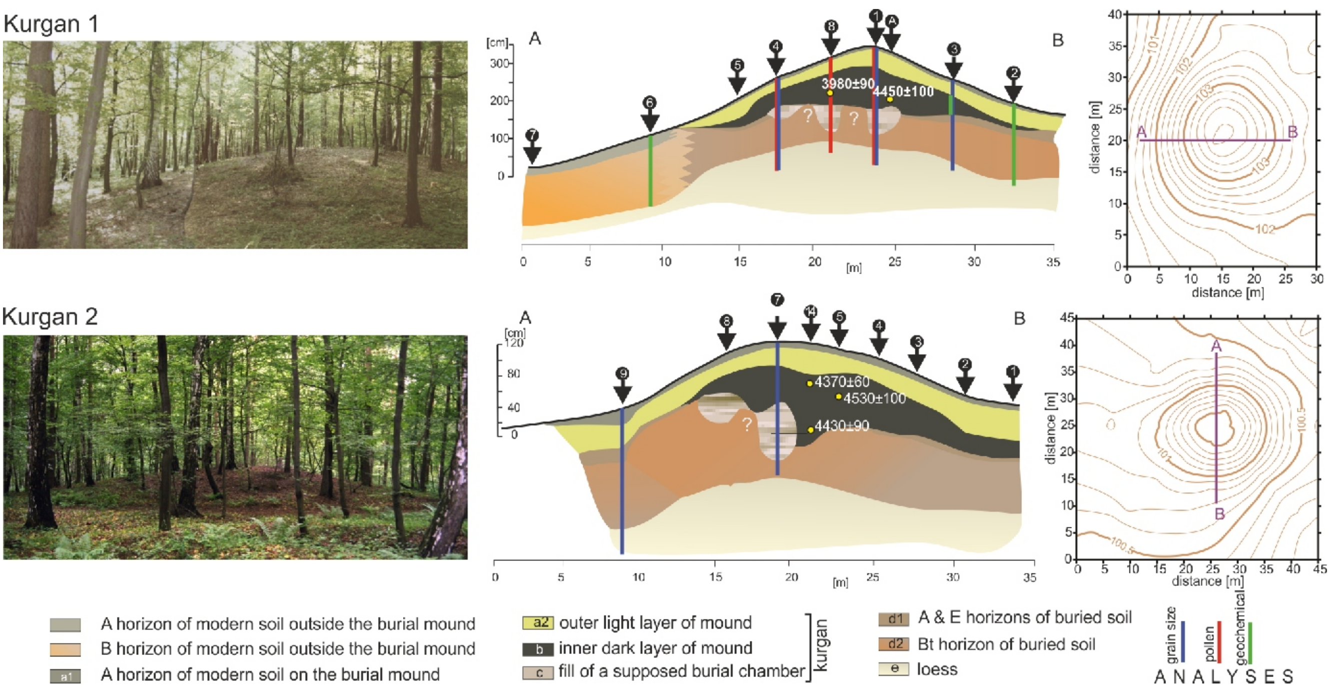

Fig. 5. Photos of kurgans 1 and 2 and geological cross-sections through these objects, according to Łanczont et al. (2003, 2007, modified)

Location of the cross-sections marked on the contour maps of the kurgans

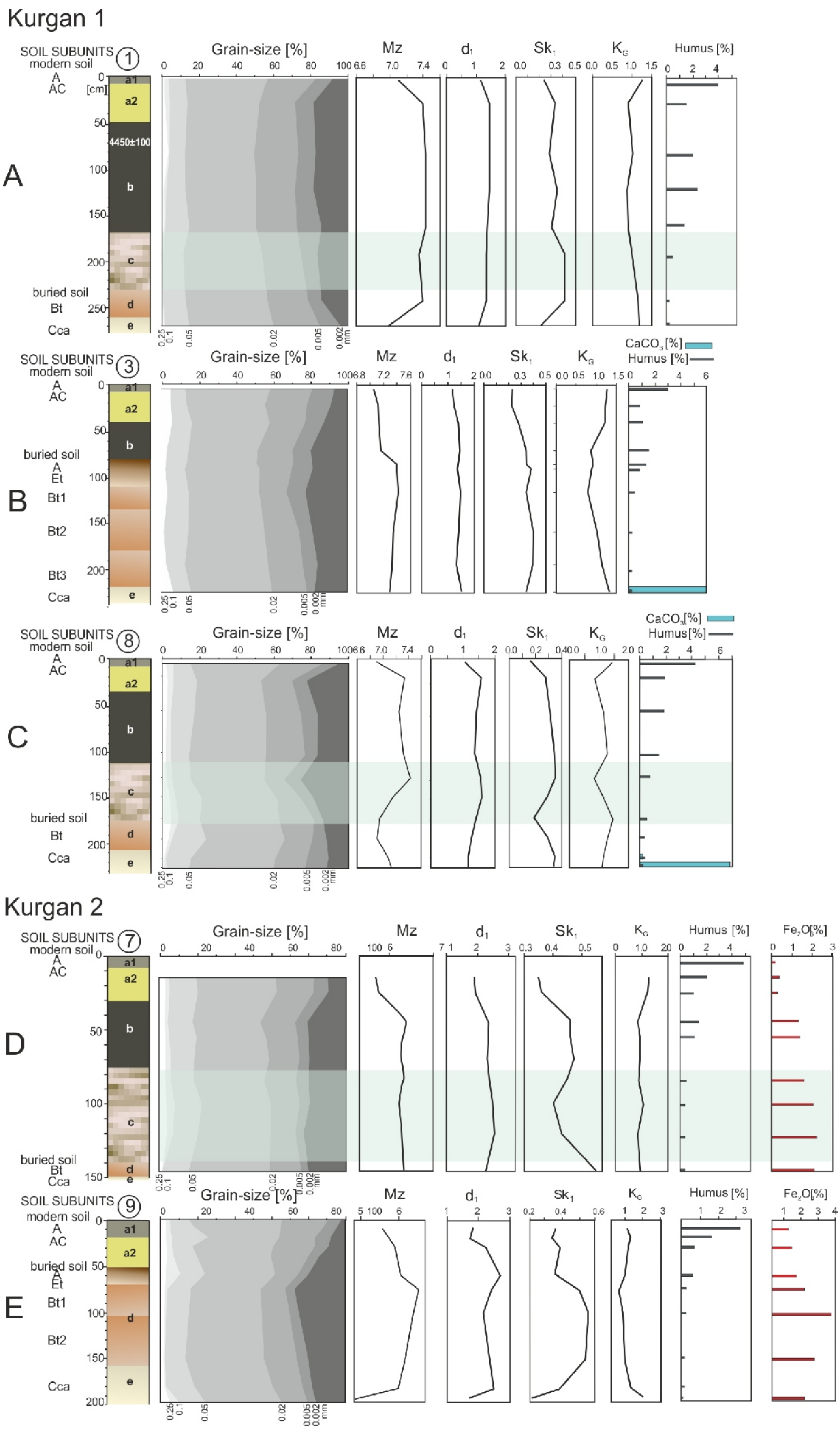

Fig. 6. The results of main lithological analyses of deposits from boreholes 1 (A), 3 (B) and 8 (C) nto kurgan 1 as well as boreholes 7 (D) and 9 (E) into kurgan 2

Explanations in the text and in Figure 5

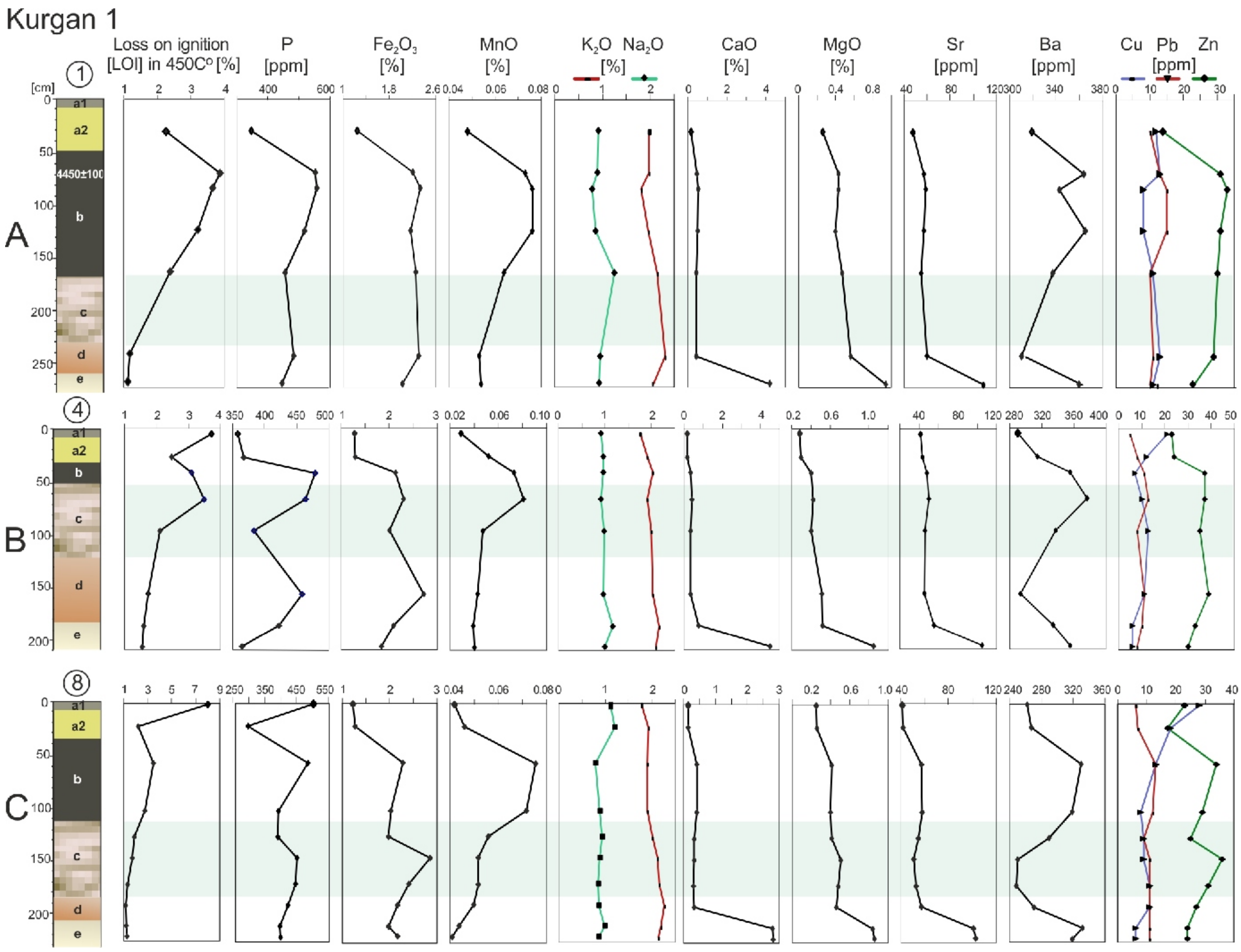

Fig. 7. The contents of main and trace chemical elements in boreholes 1 (A), 4 (B) and 8 (C) into kurgan 1, according to Łanczont et al. (2007, modified)

Explanations in the text and in Figure 5

top part (a_1) of this layer is slightly pedogenetically altered; the slightly sandy A horizon of poorly developed brownish soil is thin (10 cm) but with a high content of humus (4–7%) and, in places, also of phosphorus (500 ppm, drilling 8), nearing the values of these components found in layers b and c inside the kurgan (Fig. 7).

Inner dark layer of the kurgan cover. This dark-brown, almost black layer (Fig. 5 – layer b) is up to 0.6 m-thick, compact and very clayey. It contains a significant content of humus (1.6%), while the content of organic carbon (Corg) reaches 4% (Figs. 6 and 7). The contents of phosphorus (450–559 ppm) and Fe_2O_3 (>3%) are higher than in other parts of the kurgan.

Spatially limited lenses. The inner lenses (Fig. 5 – layer c), composed of mixed clayey material, contain >20% clay and are enriched in iron compounds (>3.5%). This material is characterized by anomalously high contents of Fe, Mn, Ba, Zn, Cu (Fig. 7B, C). The content of phosphorus is also high (400–450 ppm), but slightly lower than in the dark layer b.

Buried soil and loess. The buried soil (Fig. 5 – layer d) developed on the loess (layer e) is a luvisol with a thickness of >2 m. The complete soil profile is preserved only in places, around the zone of the supposed burial chamber. The A horizon is 0.1–0.2 m-thick, (maximally >0.4 m), and it contains >1% of humus and >2% of Fe_2O_3. The E horizon is up to 0.2 m thick, and the Bt horizon (>1.2 m thick and consisting of two or three subhorizons) is enriched in clay (>28%) and iron compounds (3–3.7%).

The granulometric indices of the loess underlying the mounds (Fig. 5 – layer e) are spatially variable: the average grain size is larger (Mz of ~5–6) and the material is less well sorted ($_1$ of 2) under mound 2 than under mound 1 (Mz ~7 , $_1$ 1). The content of Fe_2O_3, irrespective of the determination method, is 2–2.2%; the content of organic carbon is low. The loess contains 6–8% carbonates. Layers d and e are characterized by the maximum CaO contents (2.79–4.51%) due to the presence of calcite and a few percent of dolomite.

The profile of the present-day soil occurring at the kurgan margin, outside the mound, represents a cambisol type (core 6; Figs. 5–7).

INTEGRATED GEOPHYSICAL STUDIES

Geophysical methods make it possible to detect and track changes in physical parameters occurring in shallow near-surface layers. They may result from the presence of shallow objects, including archaeological ones. The methods most com-

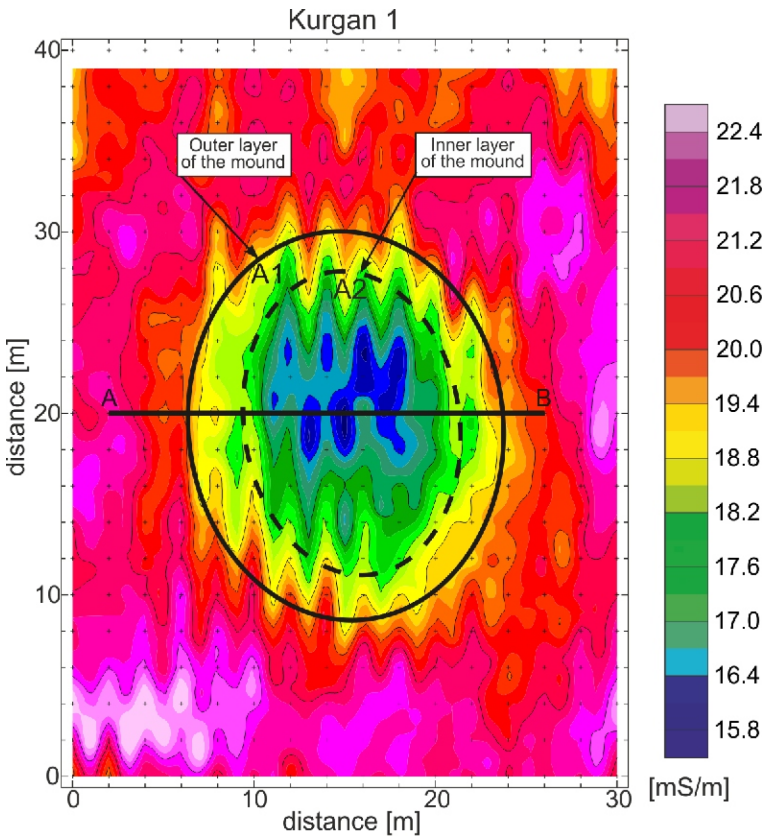

Fig. 8. Map of changes in apparent soil conductivity within kurgan 1 to a depth of h ~6 m (EM31 MK2 conductivity meter, VD)

monly used in archaeology and giving the best results are the geoelectric type (resistivity, GPR, electromagnetic) and the magnetometer method (Vaughan, 1986; Misiewicz, 1998; Dabas et al., 1999; Collier et al., 2003; Łanczont et al, 2003, 2004b; Vafidis et al., 2005; Epov and Chemyakina, 2009; Mackiewicz et al., 2016; Makarowicz et al, 2017; Hildebrandt-Radke et al., 2018; Tóth et al., 2018; Gębica et al., 2021). At least two methods should be used, though this is not very often the case (Kai et al., 2004; Persson and Olofsson, 2004; von der Osten-Woldenburg and Eberth, 2015; Cseh et al., 2022).

Conductivity study. The study area around the kurgans is characterized by high conductivity in the range of 15–22 mS/m. The notable elongated pattern of the conductivity contrasts, as mapped (Figs. 8 and 9) and plotted using the kriging method, is characteristic of conductometric methods and indicates the direction of transitions (the direction of measurement profiles). This phenomenon is particularly noticeable with the lowest conductivity anomalies.

Two oval and concentric anomalies with conductivity noticeably lower than the surroundings are clearly marked on the conductivity maps. These were labelled as anomaly A1 of larger diameter with the A2 anomaly inside it. In the zones outside the anomalies mentioned above, the conductivity significantly increases and is the highest in the entire area surveyed: above 19 mS/m. Oval anomaly A1, with conductivity in the range of 18–19 mS/m, reflects the range of the outer embankment part of the mounds (light upper layer) and, thus, the sediments from which these were built. The ratio of the longer to shorter axis is, respectively, for kurgan numbers 1 – 22:18 m, 2 – 26:18 m, and 3 – 19:16 m.

Oval anomaly A2 is characterized by conductivity in the range of 16.5–18 mS/m and reflects the range of sediments forming the inner dark layer of the mounds. The ratio of the longer to shorter axis is, respectively, for kurgan 1 – 17:13 m, 2 – 21:14 m, and 3 – 15:14 m. Inside anomaly A2, in the central parts of the mounds, there are other smaller anomalies of irregular and elongated shape characterized by the lowest conductivity, below 16.5 mS/m. In the zone of kurgan 1 (Fig. 8) and 3 (Fig. 9), there are several such anomalies; some of them occur approximately centrally and are connected to form one whole. They have oval shapes up to ~2 m long and up to ~1 m wide.

The conductivity contrast in the case of kurgan 2 is clearly smaller. Inside anomaly A2, only one small anomaly of the lowest conductivity is marked. It is shifted relative to the central point by several metres, which suggests that the current shape of the kurgan does not fully correspond to the original form.

The location of the profiles along which resistivity measurements were taken, in a later second stage, was plotted on maps of changes of conductivity.

Electrical resistivity measurement. Two measurement series were made on kurgans 1 (Fig. 10) and 2 (Fig. 11): a deeper one of up to 4 m and a shallower one of up to ~2 m (only kurgan 2). All the electrical resistivity models are similar in their interpreted thickness and resistivity values. In the deeper series (kurgan 1), measurements were made along one A-B profile with a length of 24 m. This was directly above a distinctly large low-conductivity anomaly (Fig. 8). The measurements on kurgan 2 were made along three parallel profiles: 1–1A, 2–2A and 3–3A, each 20 m long and 4 m apart. They were designed to constrain small anomalies of low conductivity (Figs. 9 and 11), in contrast to the strong anomaly intersected by the A–B profile. For their more de-

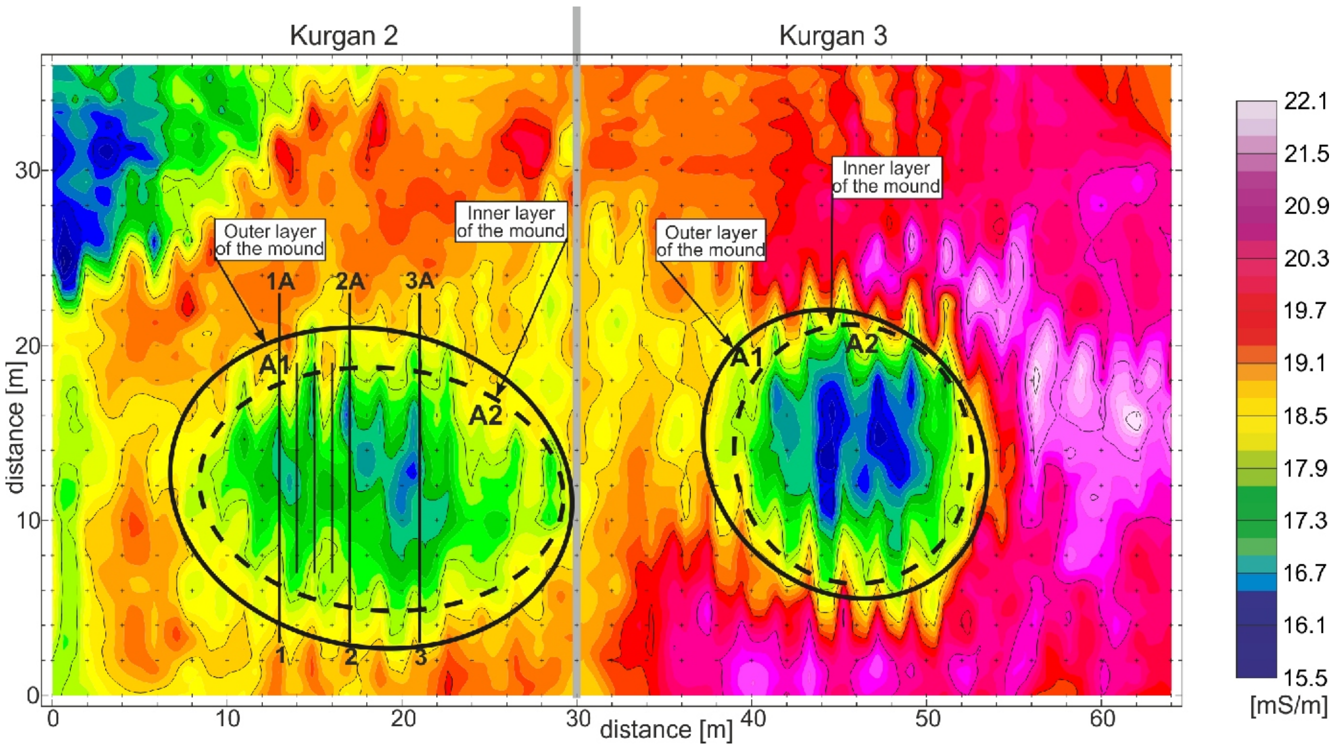

Fig. 9. Map of changes in apparent soil conductivity within kurgans 2 and 3 to a depth of h ~6 m (EM31 MK2 conductivity meter, VD)

tailed recognition, measurements were made along five parallel profiles in the shallower series: a–a1, b–b1, c–c1, d–d1 and e–e1, 12 m long and 1 m apart (Figs. 9 and 11).

All measurements were made at very high currents, in the 200–500 mA range. It demonstrates excellent electrode-soil contacts and suitable conditions for resistivity measurements. Considering the topography, the inversion of the measurement data was carried out in the *Res2D* program. The mean square error (RMS) in all resistivity sections, after 4–5 iterations, did not exceed a value of 4.

In the deeper series, at kurgan 1, resistivity values of 30–800 m were recorded. Kurgan 2 is characterized by lower values of 40–500 m. The upper near-surface layers on both kurgans are very similar to each other. They are continuous and regular, characterized by the highest resistivity values of >250 m and reaching a thickness of ~0.4 m in the top parts of the mounds and ~0.8 m on their slopes. This layer can be correlated with the outer layer of the kurgan cover together with the modern soil developed on it.

The second layer, lying below, is characterized by a resistivity value from 100 m to 250 m and a thickness of 0.2 to 0.5 m. It may be associated with the inner layer of the mounds. In the initial and final sections of the profile on kurgan 1, there are large and distinct recesses (Fig. 10). This is a presumed circumferential groove. Two such grooves are visible on kurgan 2 though only weakly (Fig. 11).

The third layer correlates with the lower layer of the mounds and may correspond to the E horizon of the buried soil. It is characterized by a resistivity value of 30–100 m on kurgan 1 and reaches a thickness of ~2.5–3 m. It is clearly heteroge-

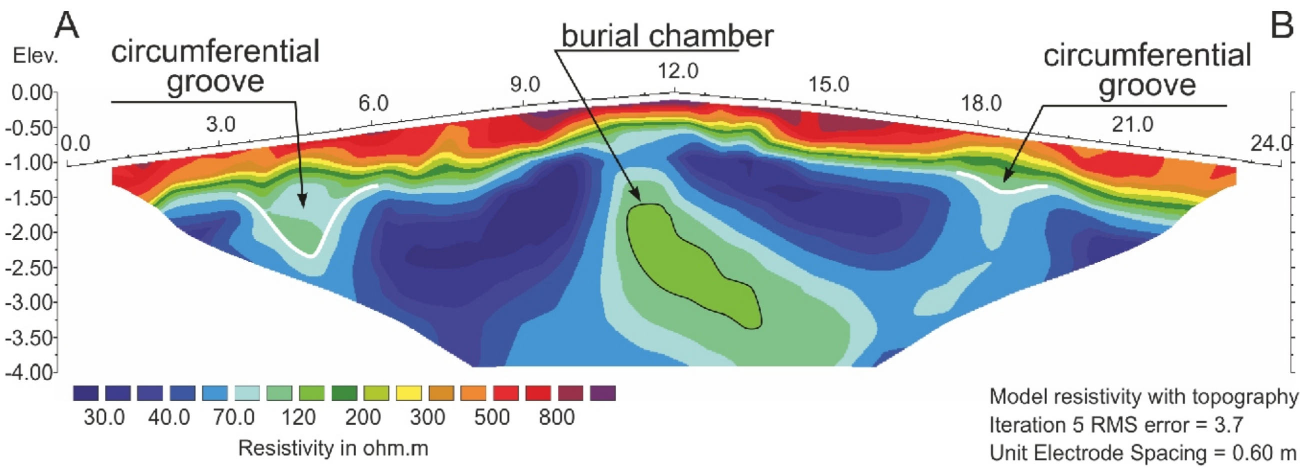

Fig. 10. Resistivity changes along measurement profile A–B in kurgan 1 (for cross-section position see Fig. 5A and 8)

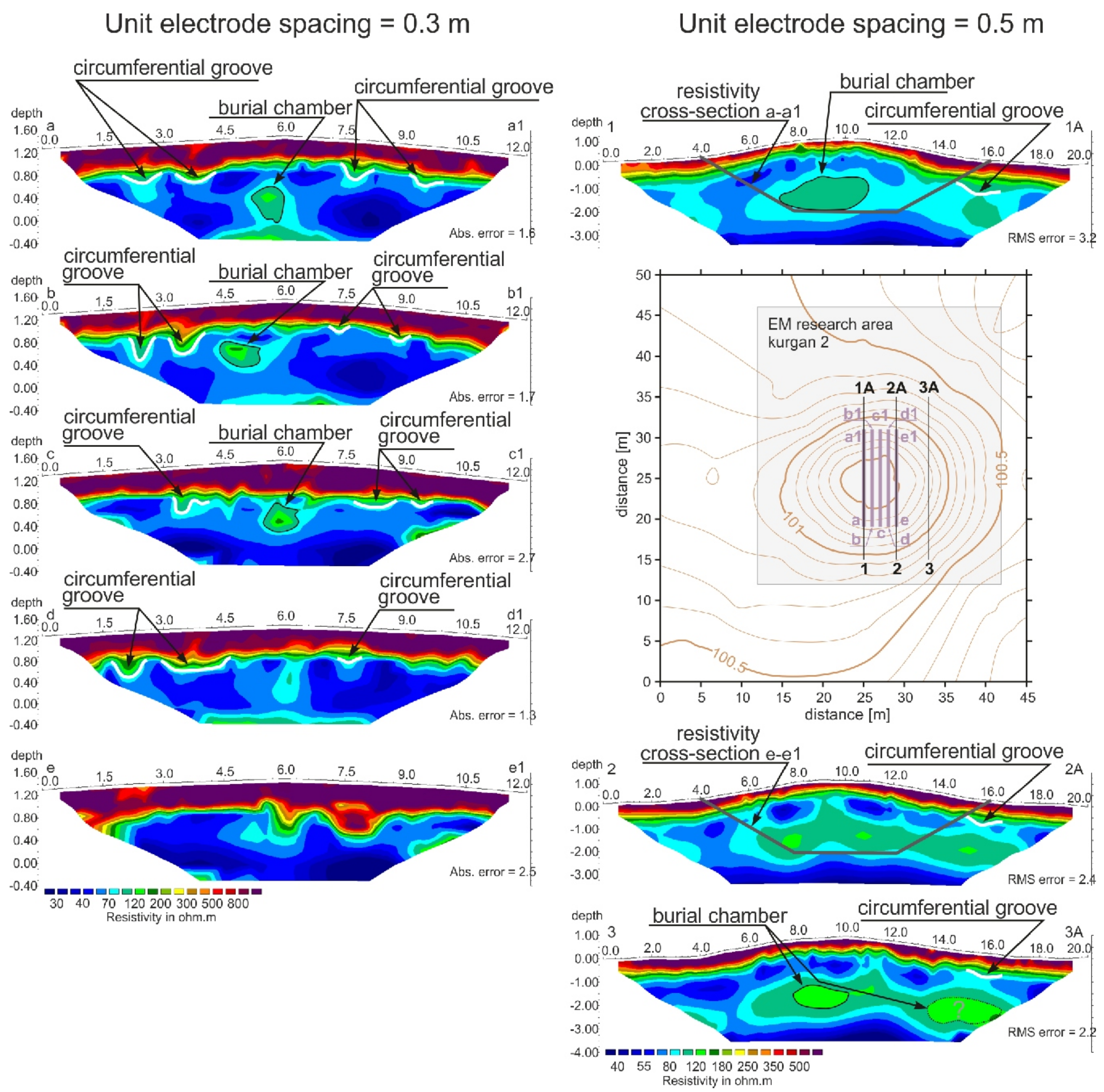

Fig. 11. Resistivity changes along measurement profiles 1A–3A (unit electrode spacing = 0.5 m) and a1–e1 (unit electrode spacing = 0.3 m) across kurgan 2

neous and disturbed. There are four shallow lenses with the lowest resistivity, <50 m, of which the two largest are in the middle section of the profile, and the two smaller ones are at their beginning and end.

In the middle part of the profile, between the anomalies with the lowest resistivity value, there is a large anomaly of increased resistivity (>100 m) with a lens with resistance >150 m. This lens, marked in Figure 10, lies between 11 and 14 m along the profile. Its ceiling is located at a depth of ~1.5 m below ground level. The third layer noted of kurgan 2 (Fig. 11) is characterized by resistivity values of 50–100 m. In its ceiling, parts are several low-resistivity lenses with a thickness of ~1 m. Some of them show a tendency to join and form an independent layer. In the central parts of profiles 1–1A and 3–3A, there is a lens with increased resistivity of 150 m. Its roof on profile 1–1A lies at a depth of 1.5 m below ground level and, on profile 3–3A, 2 m below ground level. On profile 1–1A, it reaches a thickness of ~1.5 m, and on profile 33A, ~1 m.

In the lower parts of the profiles of kurgan 2: 1–1A, 2–2A and 3–3A, at a depth of 3.5 m below ground level, one more continuous layer with the lowest resistivity, <50 m, is clearly visible. It correlates with the B horizon of the buried soil and loess substrate.

The second and shallower measurement series (Fig. 11), corroborated the stratified nature of the geological structure. The first two layers are fully marked, and their thicknesses correlate very well with the analogous ones in deeper sections. They differ only in a slightly higher resistivity range resulting from atmospheric conditions. Measurements in this series were carried out during a more extended rainless period. This is always associated with a significant reduction in moisture in the shallowest layers and, thus, an increase in their resistivity values. In the bottom of the second layer, deepenings were marked, similar to those in deeper profiles, which can be identified as two concentric circumferential grooves. Their gradual disappearance is observed on cross-sections c–c1 and d–d1. The third observed layer shows similar resistivity values to the analogous one in deeper sections, but its bottom is below the recognition depth. Due to the much more densely stabilized electrodes, their structure could be recognized in detail. Within it, in the central part of the mound, a slight anomaly with increased resistivity of 100–160 m and dimensions of up to 1 m in length and 0.5–0.6 m in thickness was found. It is visible in profiles a–a1, b–b1 and c–c1 (Fig. 11). Its centre is at a depth of 0.9 m (profile a–a1) to 0.7 m (other profiles), which may be associated with the slope of the mound. The anomaly occurs directly above the burial chamber recorded on the deeper profile A–1A, where it is invisible.

POLLEN SPECTRA OF THE DEPOSITS OF KURGAN 1 AND ITS SURROUNDINGS

Palynological investigations of samples taken from burial chamber infills, burial mounds and other archaeological sites have been carried out since the middle of the last century, usually as part of interdisciplinary research (Waterbolk, 1958; Andersen, 1973, 1988; Casparie and Groenman-van Waateringe, 1980; Makohonienko et al., 1998, Niebieszczański et al., 2019; Kurzawska and Sobkowiak, 2021). Their results differ from those of palynological sequences representing natural geological profiles and they provide other interpretation possibilities (Latałowa, 2003a). They also generate various difficulties due to such features as the state of preservation of the pollen grains and the nature of the material analysed (Makohonienko et al., 1998; Kołaczek et al., 2021). Such pollen spectra illustrate the overall composition of local or sub-regional vegetation and represent together various habitats located in the vicinity of a site (Andersen, 1992; Latałowa, 2003b). On the other hand, the results of palynological investigations into soils underlying kurgans (started in the 1940s) have been very promising (Wasylikowa, 2005).

The number of pollen and spore grains in the samples analysed from kurgan 1 varied, but they were exceptionally well preserved (Komar et al., 2003). The highest frequency of pollen grains was found in the samples taken from the dark part of the kurgan (the sum of AP, NAP and P ranged from 226 to 864 grains). Three samples from the present-day soil contained <100 grains. No charcoal particles were found in any of the samples analysed.

Buried soil. Pollen analysis of samples taken from the lessivé soil underlying kurgan 1 (Fig. 12A) indicated that a mosaic of forests grew in the area. The relatively high proportion of *Carpinus* and *Quercus* indicates that these two components formed oak-hornbeam forests (with admixtures of *Tilia* and *Corylus*). There is a remarkably high admixture of birch, most likely of local origin, which may reflect open, sparse forest vegetation. Hazel, viburnum and elder probably occurred in forest clearings and margins. The occurrence of alder grains in the spectra is an indicator of wetter habitats. Among many species of herb, the pollen of plants considered as anthropogenic indicators was also recorded. The presence of a few grains of *Juglans* is very difficult to explain. Perhaps these were redeposited from older deposits?

Dark layer of the mound cover. The pollen spectra of the samples from the interior of the mound are very similar or varied only slightly (Fig. 12B). In general, trees are represented by the same set of pollen (*Betula*, *Pinus*, *Alnus*, *Corylus*, *Carpinus*, *Quercus*), and tree birch pollen reaches the highest frequencies. The pollen frequencies of trees are higher than those of herbaceous plants. The composition of herbs is quite varied but none of the taxa occur in amounts that could indicate a special role. Local shrubs and herbs are represented by pollen of *Artemisia*, *Viburnum*, Asteracea, Cyperaceae, Cannabaceae, *Plantago*, *Rumex*, Brassicaceae and Cichoriaceae.

Present-day soil as contextual material. Pollen of trees, mainly pine, predominates in all the pollen spectra (Fig. 12C). The values of oak and birch pollen are considerably lower. However, pine and birch are strongly wind-pollinated species so they are probably overrepresented several times in pollen spectra in relation to their real abundance in the landscape (Andersen, 1973). Pollen of spruce, fir, hornbeam, elm, maple, beech, linden, ash, alder and willow is less frequent. The number of pollen grains of shrubs (hazel, viburnum, buckthorn) and herbs is low. Among herbs there are heliophilous plants, weeds and ruderal plants (Poaceae, Cyperaceae, Amaranthaceae, Asteraceae, Brassicaceae, Caryophyllaceae, Cichoriaceae, Rosaceae, *Artemisia*, *Helianthemum*; *Urtica* pollen is rarely found).

RESULTS OF RADIOCARBON DATING

The results of radiocarbon dating (in years BP) of 4 samples of allochthonous material taken from layer b in kurgan 1 and 2 are very similar: 4450 ±100 (Ki-9239), 4530 ±100 (Ki-9238), 4430 ±90 (Ki-10679) and 4430 ±90 (Ki-10679). The age of the dark layer material after calibration is in the range of ~2900–3300 cal BC, which corresponds to ~4850–5300 cal BP (Table 1 and Fig. 13). The results of radiocarbon dating seem to be in agreement with pollen data (*Carpinus*), published by Ralska-Jasiewiczowa et al. (2004) and Walanus and Nalepka (2004). Distinctly younger is the date 3980 ±90 (Ki-10681) obtained for the sample taken in the western part of kurgan 1.

OUTLINE OF THE GEOENVIRONMENTAL AND NATURAL ECOSYSTEM CHANGES IN THE KAŃCZUGA PLATEAU AND THE PREHISTORIC HUMAN IMPACT ON THEIR TRANSFORMATION

There remains the question whether the kurgans under study reflect very local (site-scale) patterns of vegetation (cf. Niebieszczański et al., 2019) or regional ones and whether we can relate the period when the kurgans were built with a specific phase of vegetation development. The answer to these questions lie in the contextualization of the palynological record from this archaeological site within the broader, general Holocene vegetation history of the central part of the Kańczuga Plateau (Fig. 14).

The oldest information about the nature of vegetation that occurred in the area discussed concerns the Late Glacial (Fig. 14). The succession of palaeosols preserved beneath the deluvial covers on the northern slopes of the Mleczka Zarzecka stream catchment was formed at that time. It consists of luvisol (TL age 11.2 ±3 ka and 10.8 ±2 ka) and superimposed gleyed meadow soil. Luvisol developed beneath an open pine forest community, probably in the Alleröd pine phase. After a hiatus recorded as an erosion surface on the top of the luvisol, pioneer plants encroached into the area. A woodless landscape was formed, with communities of heliophilous and hygrophilous plants. The gleyed soil developed under cold climatic conditions

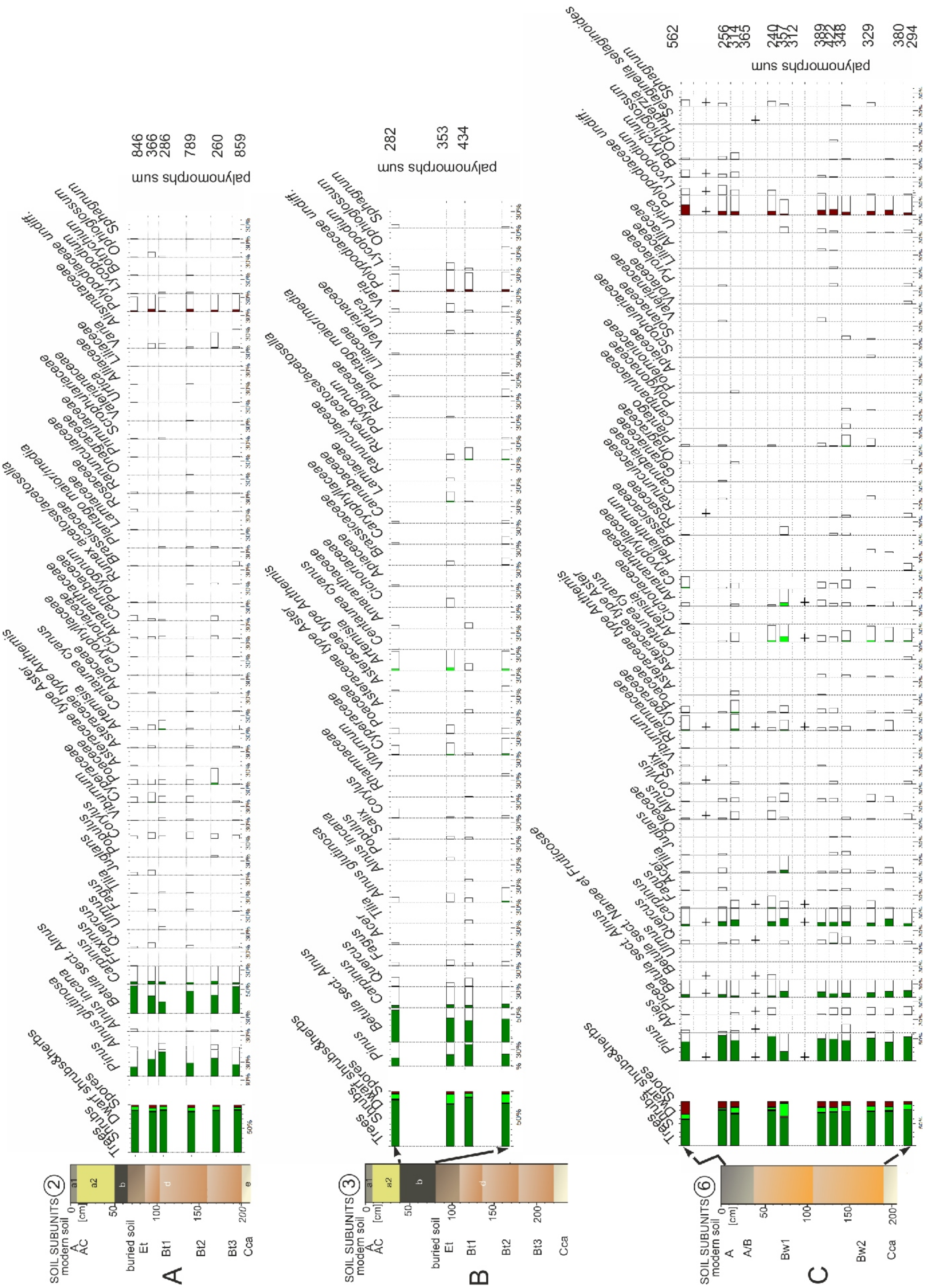

Fig. 12. Kurgan 1, pollen histograms of samples from boreholes 2 (A), 3 (B) and 6 (C)

Table 1

^{14}C ages and calibration results (Ox.Cal 4.4.4) of the charred organic fraction in samples collected from the dark layer of the studied kurgans

Age BP	Cal BC	Cal BP	Borehole numbers	Depth	Lab. code
Kurgan 1					
3980±90	**2705–2272 (84.1%)** 2864–2804 (5.0%) 2259–2205 (3.6%) 2759–2718 (2.7%)	**4654–4221 (84.1%)** 4813–4758 (5.0%) 4208–4154 (3.67%) 4708–4667 (2.7%)	8	0.9–1.1	Ki-10681
4450±100	**3371–2896 (95.2%)** 3482–3478 (0.2%)	**5320–4845 (95.2%)** 5431–5427 (0.2%)	A	1.2–1.4	Ki-9239
Kurgan 2					
4530±100	**3386–2924 (84.3%)** 3515–3422 (9.7%) 3414–3393 (1.4%)	**5335–4873 84.3%)** 5464–5371 (9.7%) 5363–5342 (1.4%)	5	0.6	Ki-9238
4370±60	**3113–2887 (81.9%)** 3328–3224 (11.2%) 3181–3155 (2.4%)	**5062–4836 (81.9%)** 5277–5173 (11.2%) 5133–5104 (2.4%)	14	0.55–0.6	Ki-10678
4430±90	**3555–2906 (95.4%)**	5304–4855 (95.4%)	14	1.1–1.25	Ki-10679

Results of C-14 dating (Ox.Cal 4.4.4)

and variable humidity, probably as early as the last part of the Vistulian period or the beginning of the Holocene (Łanczont et al., 2006).

Environmental changes occurring in the catchment and its surroundings during almost the whole Holocene (excluding the Preboreal) are recorded in organogenic deposits filling the valley bottom in the area of the Old Swamps wilderness (Zernickaya et al., 2003; Alexandrowicz et al., 2003, 2021; Klimek et al., 2006). Accumulation of sandy alluvium underlying the organic deposits occurred 12 to 14 ky ago (Łanczont et al., 2004).

Pollen analysis indicate that the natural changes of plant communities growing on the hills surrounding the valley were periodically disturbed by human impacts (Fig. 14). The periodic appearance of various settlement groups on the Kańczuga Plateau and their economic activity (Nogaj-Chachaj and Łanczont, 2012) resulted in the transformation of the natural environment, involving the clearing of forests, the increasing significance of pioneer trees, shrubs and meadow plants, the appearance of weeds. The first disturbances of the forest cover which can be related to human presence in the area described occurred in the second half of the middle part of the Atlantic period. These may be attributed to intentional activity (local burning) by Mesolithic peoples or to the agricultural economy of the Early Neolithic communities. The second stage of anthropogenic impacts occurred at the turn of the Atlantic and Subboreal periods and may be related to the economic activity of people belonging to the broadly understood Lengyel-Polgár circle and Funnel Beaker culture (Kadrow and Zakościelna, 2000; Dębiec et al., 2015; Rybicka, 2016; Król, 2017, 2018, 2019; Rybicka et al., 2017). This stage was characterized by an increasing proportion of plants indicating the enlargement of forest clearings, the appearance of weeds, ferns (bracken), and the occurrence of charcoal particles in deposits as a fossil indicator of human-induced and/or natural fire. Groups of pastoral people of the Corded Ware culture, which intensively penetrated the loess

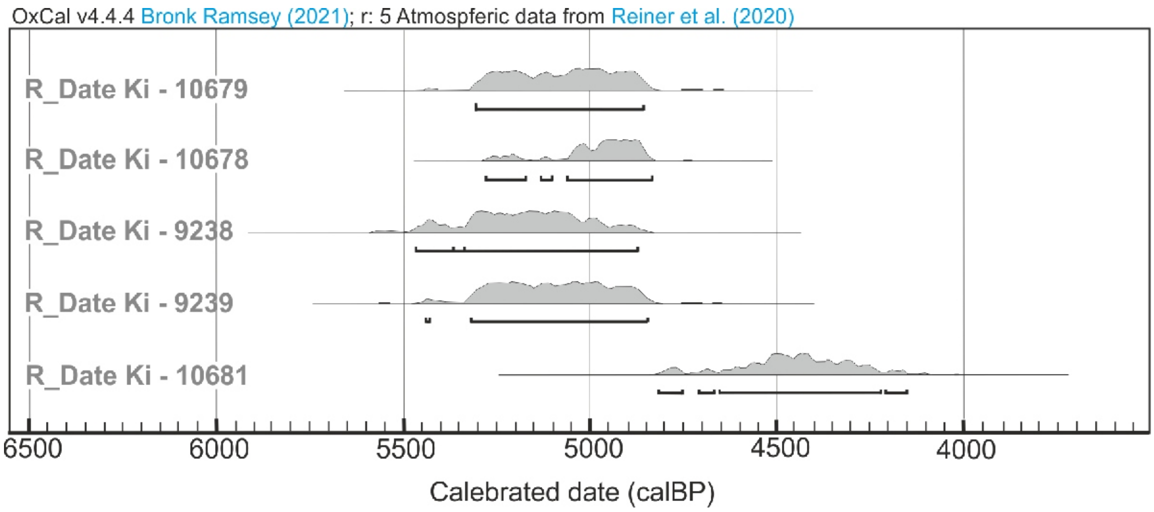

Fig. 13. Calibrated radiocarbon ages of samples collected from the dark layer of the kurgans studied

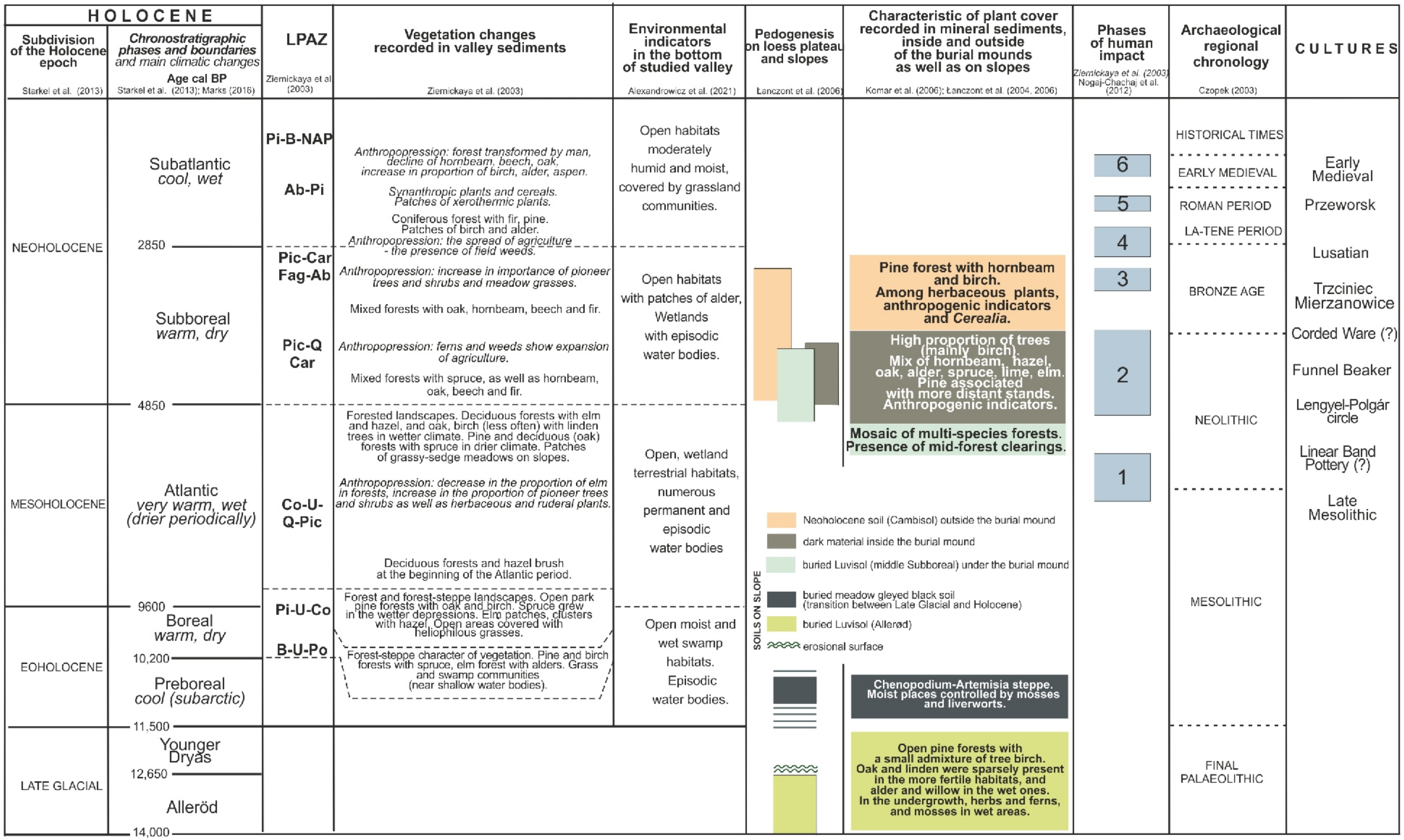

Fig. 14. Phases of prehistoric economic activity in the area studied against the background of environmental changes and periods of pedogenetic development, according to Łanczont et al. (2006) and Nogaj-Chachaj, Łanczont (2012), supplemented and modified

area of the Kańczuga Plateau as the Neolithic gave way to the Bronze Age, led a semi-nomadic life and did not leave a distinct record in the pollen spectra of the valley-fill deposits (Machnik, 2019). The third stage of economic activity is related to the Bronze Age. In the catchment studied this stage left archaeologically evidence in the form of remains of settlements and objects of the Trzciniec and Mierzanowice cultures (Nogaj-Chachaj and Łanczont, 2003, 2012). In this period the proportions of pine, hornbeam, beech and fir in the forests decreased and the significance of pioneer trees and shrubs increased. The fourth phase of anthropogenic activity and the spread of agriculture, marked by the occurrence of field weeds, is related to the Lusatian culture; settlement by this people was very well developed and intensive close to the catchment (Zernickaya et al., 2003; Nogaj-Chachaj and Łanczont, 2012). The next revival of the economy occurred in the period of Roman influence, with cereals among the indicator plants (Zernickaya et al., 2003). During this period the activation of settlement and agriculture resulted in an increased intensity of soil erosion and in alluviation of small valleys (Klimek et al., 2006; Nogaj-Chachaj and Łanczont, 2012). The sixth stage of anthropogenic impacts occurred in the early Middle Ages. At that time patches of meadow and more xerothermic vegetation spread and new synanthropic plants appeared.

The results of natural, archaeological and historical research indicate that settlement and economic activity in the surroundings of the Old Swamps wilderness took place mainly on the flat tophills and their slopes (Łanczont et al., 2006). This is why the malacological data obtained for the valley-fill deposits show no signs of human influence (Alexandrowicz et al., 2003, 2021). Throughout the Holocene, the valley bottom was occupied by woodless habitats, with local and temporary occurrence of small alder patches. The wetter phases, especially in the middle Holocene, were characterized by a more diverse mosaic of aquatic-boggy-meadow habitats and by the occurrence of shallow but permanent, heavily overgrown small lakes. These became ephemeral during the less humid phases until they finally disappeared in the Subatlantic period when they were partially replaced by drier meadow habitats (Fig. 14). The lack of traces of human economic impact on the environment of the valley bottom, which was more or less boggy and hard to access throughout prehistory, may indicate that it was a kind of ecological barrier to any human activity. Historical data confirmed that this situation lasted until the first half of the 20th century when the area was drained.

A REVIEW OF ARCHAEOLOGICAL RESEARCH INTO THE CORDED WARE CULTURE KURGANS IN THE NORTHERN SUBCARPATHIANS

Kurgans in the Northern Subcarpathians are commonly related to various stages of the Corded Ware culture development; they were usually built with a significant amount of effort (Kruk and Milisauskas, 1999; Jarosz, 2011; Włodarczak, 2011; Machnik, 2019). Commonly, several graves of this culture are grouped, and so they form small necropolia. In some of these, besides normal graves, there are mounds over individual burials. Archaeological excavations have only been conducted at some kurgans so it is difficult to clearly define the function of many sites as burial places. The graves of the Corded Ware culture with the remains of partially preserved mounds have been examined by excavation at the Szczytna site (Hozer et al., 2017), in the area of Mirocin (Machnik et al., 2019), and at the Średnia (Machnik and Sosnowska, 1999) and Wola Węgierska (Machnik and Sosnowska, 1998) sites located in the Dynów Foothills. Graves of the Corded Ware culture have also been investigated at the Skołoszów (Rybicka, 2016) and Święte (Kośko et al., 2018; Olszewski and Włodarczak, 2018) sites located on the Upper Pleistocene loess terrace of the San River (Rybicka et al., 2017).

The Corded Ware culture kurgans, occurring on the Kańczuga Plateau, are arranged in two almost parallel chains, usually located ~800–1000 m from each other (Fig. 15). These were built by communities of the same culture but not at the same time. Despite much information regarding their absolute age, the sequence of their construction has not been determined at the present stage of research. Their age can be generally estimated (Kruk and Milisauskas, 1999; Machnik, 2011; Jarosz, 2011), and lasted until the beginning of the Bronze Age (Włodarczak, 2017) at 4900–4100/4000 cal BP (2800–2200 cal BC). Archaeological excavations indicated that in the areas where burial objects and kurgans of the Corded Ware culture were found (e.g., Szczytna, sites 5 and 6; Mirocin, sites 24 and 27), both settlements and necropolia of the Funnel Beaker culture existed in earlier times (Mazurek et al., 2016; Jarosz and Machnik, 2017, Jarosz et al., 2019; Machnik, 2019; Machnik et al., 2019). This means that the natural environment (prior to the kurgans' construction) may have already been considerably transformed. Economic activity of these communities took place at 5600–4900/4800 cal BP (3700–3300/3200 cal BC).

In the light of the current archaeological research on the Subcarpathian kurgans, it can be concluded that the funeral rite resulting in their construction was rich and laborious, and required careful work on a previously prepared site. Preparatory work included burning the vegetation at this place, as indicated by the charcoal layer found beneath kurgans, or ground levelling, the traces of which were also identified during excavation (Machnik et al., 2008). In order to mark the extent of the mound, circumferential grooves were dug, which had also ritual and magical functions (separating the world of the living from the world of the dead) and probably protected the mound against erosion (Jarosz, 2011; Machnik, 2019). During the investigations of the kurgans, so-called near-kurgan pits, often called clay-pits, were also found. The earth used to build the kurgans was probably taken from these pits. This practice was commonly used by the communities of the Corded Ware culture (Jarosz, 2011), and the pits had different shapes depending on the area of their occurrence. In the Carpathian Foothills, they were located around the kurgan mound and their shape was irregular (e.g., Bierówka, Średnia, site 3, kurgan 2; Gancarski et al., 1986, Machnik and Sosnowska, 1998, 1999). The large pits known from the Sokal Plateau-Ridge are crescent-shaped (Machnik et al., 2009).

The original height of the kurgans built by the population of the Corded Ware culture in the area of SE Poland was ~2 to 4 m and the diameter was 10–20 m. Usually, under the central part of the mound, there is one grave (burial), of E–W (more often) or N–S orientation (Machnik, 1995), with the remains of one person placed in a contracted position. Most often, the bones are very poorly preserved. The dead were equipped with ceramic ware decorated with a cord ornament, flint and sporadically bone tools, and stone axes (Machnik, 1994, 2001; Machnik and Sosnowska, 1996; Machnik et al., 2000; Włodarczak, 2011).

There are also known mounds (over graves), in which succeeding graves were dug (Machnik et al., 2011). For example, several graves with different orientations were found beneath one earth mound in Średnia (Machnik and Sosnowska, 1996, 1997,1999). Archaeological excavations conducted during the construction of the A4 motorway discovered cist burials in the kurgans, previously unknown in this area (Jarosz and Machnik,

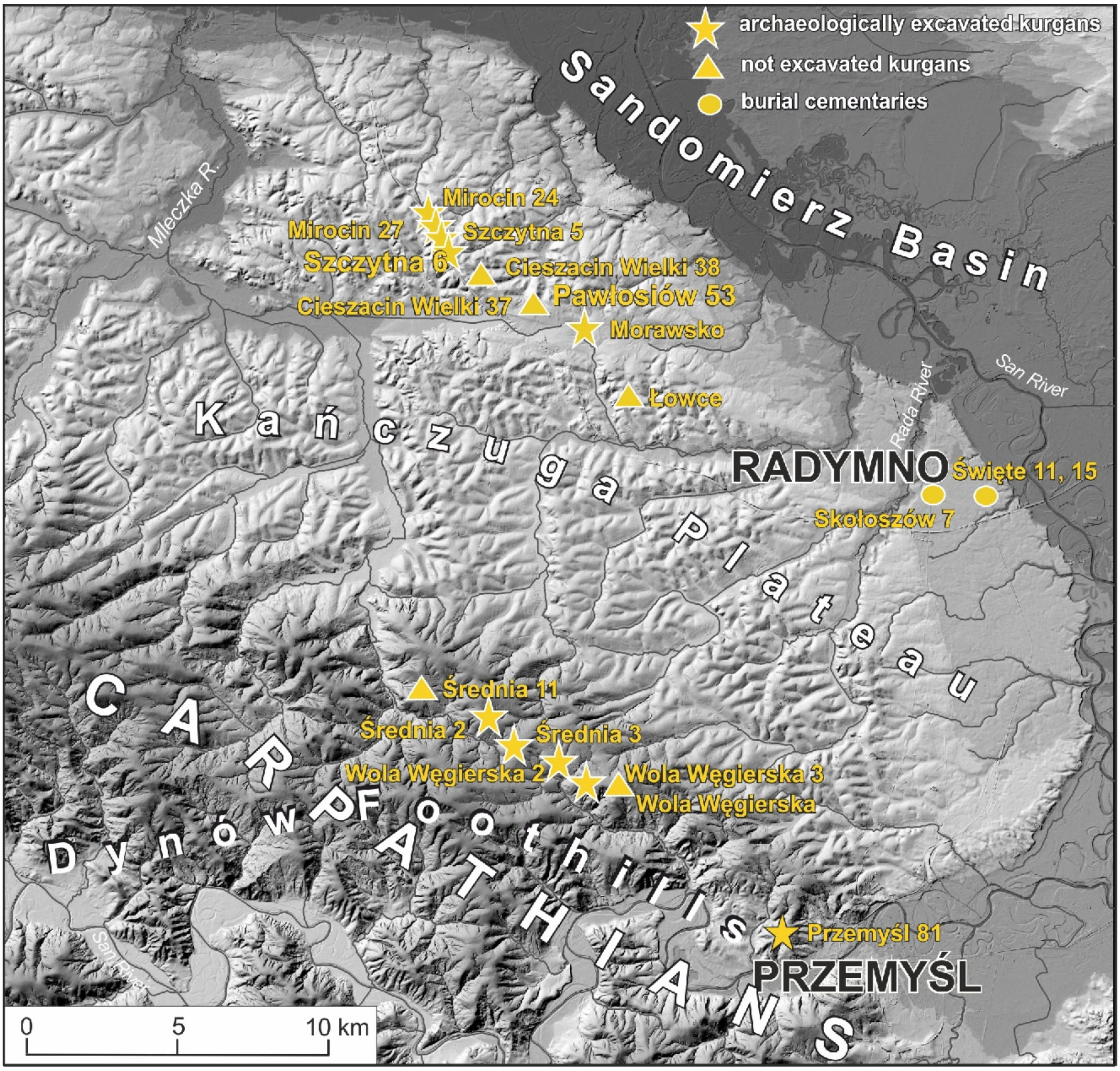

Fig. 15. Sites of archaeologically excavated kurgans in the vicinity of the study area mentioned in the text

2017). These forms are larger than the additional graves noted above that were dug later, and they are characterized by corridors leading to the main burial chamber.

HOW, WHEN AND IN WHAT NATURAL ENVIRONMENT DID PEOPLE OF THE CORDED WARE CULTURE BUILD THE KURGANS IN STUDY AREA?

A striking feature of the structure of the kurgans in Cieszacin Wielki and of other objects studied, e.g. in the marginal zone of the Polish Carpathians and in the Ukrainian Eastern Subcarpathians (Machnik and Sosnowska, 1996, 1998, 1999; Machnik et al., 1997, 2000), is the occurrence of dark and light layers within a mound.

On the maps of changes in electrical conductivity within the kurgans near Cieszacin Wielki, the spatial extent of both layers is very clearly visible (Figs. 8 and 9) as two, generally concentric, anomalies. The thickness of these layers, roughly outlined by boreholes, was constrained based on the resistivity changes along the cross-sections (Figs. 10 and 11), which revealed that the outer layer varies in thickness from 0.4 m at the mounds' culminations to 0.8 m on their slopes. This indicates that the outer layer was reduced on the upper parts of mounds due to denudation, the material being redeposited downslope. The varied layout of the land around the mounds, e.g. due to the proximity of pits dug during their construction, may have enhanced natural denudation on the steeper slopes. The inner layer, also with spatially varied thickness (0.2–0.5 m), descends to small but distinct circumferential grooves around the bases of the mounds; a single groove was discovered around kurgan 1, and two grooves around kurgan 2 (see Machnik, 2019). Furthermore, on the conductivity maps, near the central part of each mound (Figs. 8 and 9), a set of smaller, irregular and elongated internal anomalies forming one patch is visible. These anomalies show the exact location of burial chambers that were approximately determined by the boreholes. Two such objects are visible as anomalies on the western side of kurgan 1 (Fig. 8). The radiocarbon age (4654-4221 cal BP) of sample Ki-10681 taken from the dark layer may be related to one of these anomalies (Figs. 5 and 13). Provided that the age of this sample is not underestimated, this age would indicate subsequent work within the existing mound, later than its main structure was built. The resistivity changes along the single cross-section of kurgan 1 gave a less detailed picture of the burial chamber – one large anomaly 3 m long indicates its central location. Two burial chambers can be distinguished based on the resistivity changes along the sequence of cross-sections through kurgan 2: one is central, 1.5–1 m thick, and another probably occurs in the northern part of the mound. In both mounds, these objects occur in the E horizon of the buried soil underlying them, as also indicated by boreholes. The resistivity changes along the shallower cross-sections through kurgan 2 indicate the occurrence of one more anomaly, which is located over the central burial chamber noted above. This anomaly represents a smaller burial chamber, with the dimensions ~1 m x 2 m x 0.5 m, which was dug later into the existing mound. Due to its slightly deformed shape, it can be interpreted as a cist burial. The occurrence of additional burials within the kurgans may have deformed both their original shape and the arrangement of the layers, as is indicated by observations in other burial grounds used repeatedly over longer periods of time.

The occurrence of dark and light layers within the mounds is – in our opinion – not the result of intentional action related to burial practices. This feature is partly caused by natural factors and partly results from the method of the construction of a kurgan, as a technical aspect. The geochemical composition of these two layers is clearly different, despite the influence of younger pedogenesis. The constructors of kurgans used first the material collected evenly from the surface part (A horizon) of the soil in the vicinity of the grave object. At present, this is a dark and compact humus layer with an elevated phosphorus content, which indicates that human activity took place earlier at this site. The presence of phosphorus is archaeologically important as a reliable indicator of anthropogenic impact on the natural environment both past and present. A phosphorus content of phosphorus of >200 ppm is considered indicative of an anthropogenic horizon (Brzeziński et al., 1983; Konecka-Betley and Okołowicz, 1989; Bednarek et al., 2003). A trend similar to that found in Cieszacin Wielki is shown, for example, by analytical results obtained by S. Skiba (in Machnik et al., 2011) of organic phosphorus in kurgans of similar structure at the Hayi Nizhni site near Drohobych (western Ukraine). The dark layer of the kurgans near Cieszacin Wielki is also characterized by an increased contents of iron and zinc and lower contents of manganese, barium, strontium and copper (Łanczont et al., 2007) than in corresponding surface layers of Polish silt and loamy soil (Kabata-Pendias and Pendias, 1999). Thus, the dark layer is most probably the remnant of an older Neolithic cultural layer, collected from the ground surface during the construction of the mound and used to build a cover over the burial site. The radiocarbon dating results of 4 out of 5 samples taken from this layer are very similar (Table 1 and Fig. 13), indicating that the material of this layer was formed ~4800–5300 cal BP, and so taken from a cultural layer related to the activities of the Funnel Beaker culture population whose multi-phase settlement and cemetery are located in nearby Pawłosiów (Rybicka, 2011; Król, 2017, 2018, 2019).

The buried soil beneath kurgan 1 has an undisturbed profile of luvisol. Similar soils were found under the kurgans of the Corded Ware culture in the Sokal Plateau-Ridge (Licznar and Maruszczak, 1998). Pollen spectra obtained from this soil (Fig. 12A) – assuming that the successive samples represent a pollen succession – correspond to L PAZ Picea-Quercus-Carpinus zone recorded in the valley deposits (borehole I/6). The soil likely developed in the Subboreal period, when *Carpinus* encroached upon the area (Zernickaya et al., 2003). The soil underlying the kurgan developed under a multispecies, mainly deciduous forest. The forest cover was not continuous due to the presence of clearings (also Zernickaya et al., 2003). The occurrence of pollen grains of anthropogenic indicators in soils (Fig. 12A) and valley deposits (Fig. 13) indicates activity of the Neolithic populations inhabiting the surrounding areas at that time, as well as the predecessors of the Corded Ware culture community.

The earth for completing the mounds (light layer) was exploited mainly from the pits located next to the kurgans. The original features (colour, grain size) of the light layer (Fig. 6) are probably blurred and changed due to post-depositional soil processes. The migration of iron compounds and colloids deep into the soil profile resulted in the lightening of this layer and impoverishment of its composition, with the dark layer being enriched in these components. The weak development of the present-day soil covering the kurgans indicates that soil formation probably occurred simultaneously with the lowering of the mound by denudation.

The pollen spectra (Fig. 12C) obtained from the contextual borehole in brown soil in the pit on the western side of kurgan 1 (the development if which started on the newly exposed loess surface), indicate possible correlation with the LPAZ Picea-Carpinus-Fagus-Abies zone recorded in deposits of the Old Swamps wilderness, from the proportion of *Carpinus* and *Fagus* pollen and significant values of *Picea*. At that time, forest landscapes prevailed in the catchment (Fig. 14), and the proportion of herbaceous plants reached 10%. The proportion of anthropogenic indicator plants in this area was then low but noticeable (Zernickaya et al., 2003; Łanczont et al., 2004a).

By contrast, pollen spectra obtained from the dark layer of this kurgan (Fig. 12B) are quite uniform indicating that the humic earth was mixed when the builders scooped it up *en masse* to cover the burial chamber. Therefore, they should be interpreted cautiously, although it can be assumed that their taxonomic composition generally corresponds to the average composition of sporomorphs fallen in the vicinity of the site (Makohonienko et al., 1998). Generally, these spectra indicate the occurrence of open forest communities with clearings. It is inferred that the Funnel Beaker culture population, which preceded the Corded Ware culture communities in upland loess areas of dry forest, conducted extensive slash-and-burn cultivation with cereal crops. This population also raised cattle, goats and sheep in a form evolving towards nomadic seasonal pastoralism (Kruk, 1983; Valde-Nowak, 1988). The economy of the Corded Ware culture population was based on rotational grazing, with predominant long-distance migrations. According to Kruk (1983), the main grazing zone may have been forests and mid-forest clearings, where slash-and-burn methods were used to clear the area for pastures. It is in such clearings that the kurgans were probably built when a community member died while grazing their herds there.

In the case of the Cieszacin Wielki kurgans, deforestation of the surface of loess hilltops was probably not common. The absence of microscopic charcoal fragments in the pollen spectra (representing not only the dark layer but also the soil beneath the kurgan) precludes the removal of trees by burning, which would indicate that forest clearings were rather quasi-natural as drier habitats of loess hilltops. It is possible that the tree succession in the clearings was hindered and open areas in forests increased as a result of using young shoots and tree leaves as feed for animals raised by humans as suggested by Valde-Nowak (1983).

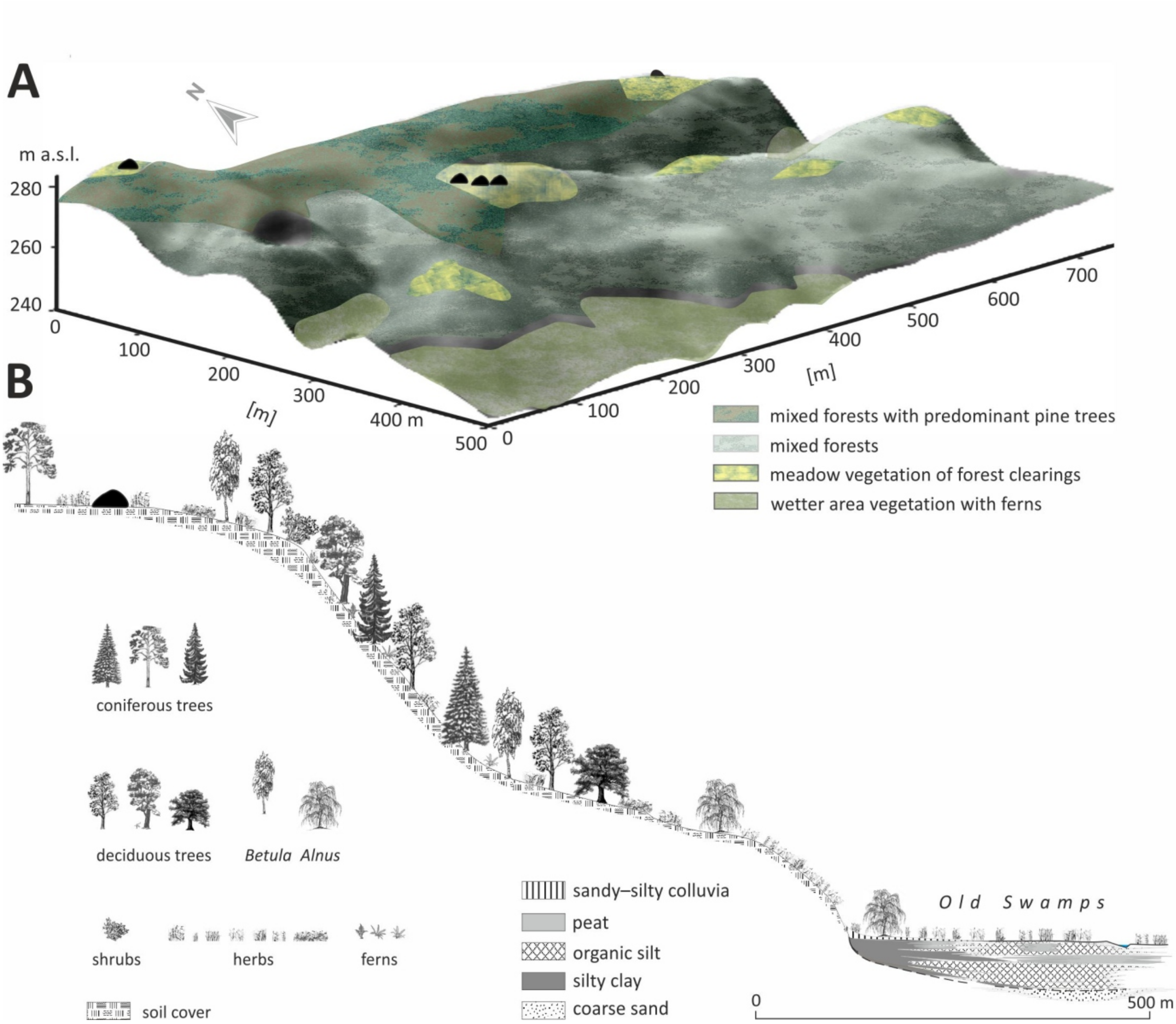

Fig. 16. Vegetation in the study area in the period of the kurgans' construction

A – schematic reconstruction of the vegetation communities close to the kurgans; **B** – composition of plant communities along a cross-section across the Old Swamps valley

The pollen spectra representing the dark layer (Fig. 12B) and the buried soil beneath kurgan 1 (Fig. 12A) are generally similar. However, in the dark layer, the frequency of tree pollen is clearly higher than that of herbs, and among the trees the very high value of birch pollen is striking. The number of birch pollen grains significantly exceeds the number of pollen grains of other AP components. This phenomenon of high birch representation cannot be explained by the colonization of open deforested areas, which is typical of this pioneer species. Possibly, at that time the mixed forests were characterized by a very high proportion of tree birch (local/extra-local aspect). However, the comparison of pollen spectra obtained from the deposits (Fig. 12B) occurring inside kurgan 1 to those representing natural soil profiles (sampled beneath and next to this kurgan; Fig. 12A,C) shows that birch predominated in the forests in none of the pedogenesis periods. Therefore, the high representation of birch pollen (with the maximum in the top sample) may indicate both that birch trees growing in the vicinity of the burial mound produced large amounts of pollen during funeral rites and that decorations made of blooming birch twigs were intentionally placed on the surface of a fresh mound over the burial chamber.

Flowers probably played an important role in the funeral rites; the burial practices used by the builders of kurgans may have included decorating a fresh grave with available ornamental plants, i.e. blooming birch twigs, which at the same time may have prevented the grave from being washed away by rain. Archaeobotanical or palynological finds related to human spiritual culture are rarely described in the Polish archaeological literature. It is also difficult to prove that plant remains or pollen discovered at archaeological sites were connected with any ritual activities. However, plants, including birch, undoubtedly played a significant role in both the material and spiritual life of prehistoric peoples (Wasylikowa, 2005).

The reconstruction of the landscape (Fig. 16) in which the kurgans were built was based on the pollen spectrum of the sample taken from the top part of the undisturbed palaeosol underlying kurgan 1, with the assumption that this sample best represents the vegetation at the time of its construction. However, this is only a general interpretation. The kurgan was located in the open space of a local hill which was surrounded by forests, mainly deciduous (Fig. 16A). Closer to the kurgan there were probably birch stands, and more open vegetation, and somewhere relatively nearby there were stands or even woods of hornbeam (Fig. 16B). The steeper, near-valley parts of the slopes were overgrown by herbaceous communities while the valley bottom was occupied by grass with alder clumps (Fig. 14, see also Alexandrowicz et al., 2022). In any case, the kurgans were built in a culturally transformed landscape. The noticeable proportion of hornbeam may reflect a secondary (coppiced) forest.

CONCLUSIONS

The four kurgans investigated, located near Cieszacin Wielki on the Kańczuga Plateau, are exceptionally valuable archaeological monuments with their own landscape shape and belong to a chain of kurgans built on prominent loess hills of the Carpathian foothills. Three kurgans form a characteristic small necropolis, and the fourth is located nearby. Non-invasive, multidisciplinary investigations of the kurgans were carried out, as a first attempt at their comprehensive study without systematic excavations.

1. The combination of geological and palaeeocological methods proved a very useful tool for pre-excavation, non-invasive recognition of archaeological features from the Neolithic period. Based on the results obtained results, it was possible to describe the structure, stratigraphy and chronology of the burial objects, to reconstruct the probable methods used for their construction, and to determine the features of the palaeolandscape in their surroundings.

2. The dimensions of the kurgans (height and diameter of the base) approximately correspond to the size of similar kurgans left by Late Neolithic communities of the Corded Ware culture, which penetrated south-eastern Poland in the period 4900–4100/4000 cal BP (2800–2200 cal BC). They seem not to have been built simultaneously, though spanned a modest time interval.

3. The kurgans were built of earth taken from their immediate vicinity and each mound cover consists an outer light and an inner dark layer. The latter, with a higher content of phosphorus, is the remnant of a cultural layer, probably left by the community of the Funnel Beaker Culture that earlier inhabited this area. This is indicated both by the results of pollen analysis of the dark layer and the results of radiocarbon dating of humus pointing to the period 5300–4800 cal BP (3300/3200–2800 cal BC) as the time of its formation. As the kurgans are built of the older cultural layer gathered around them, they must be younger than it. This cultural layer – material used for the dark layer of mounds – is probably the remnant of a small camp (or settlement) of the Funnel Beaker Culture population, in terms of time and culture related to the two-phase settlement in Pawłosiów, site 52, dated at 5600–4900/4800 cal BP (3700–3300/3200 cal BC), located to the SE of the kurgans studied, on the edge of the Old Swamps wilderness.

4. Geophysical investigations using by continuous electromagnetic-conductivity profiling and electrical resistivity imaging were carried out on kurgans 1–3. They show that each mound comprises two cover layers, and also indicate the existence of circumferential grooves running around the mound and several anomalies inside it. The anomalies are oblong ovals (~220–200 x 100 cm) of mainly N–S and E–W orientation; smaller anomalies with slightly deformed shapes are typical of cist burials. The sizes of the anomalies are similar to the dimensions of burials beneath kurgans at other sites of the Corded Ware culture in the area (e.g., Średnia, site 3; Wola Węgierska, site 3). The orientation of the graves in these comparable, excavated kurgans varies, with dominant E-W and NW-SE directions.

5. That some kurgans were used as a place of later cist burials by people of the Corded Ware culture is indicated by the date 4654–4221 cal BP obtained for kurgan 1, which corresponds well with the period of activity of this culture in SE Poland.

6. Based on pollen analysis of the dark layer, the mound was likely decorated with blooming birch twigs after the first stage of kurgan construction (the formation of the inner layer). This practice may have been an expression of magical and ritual ceremonies taking place around the grave (graves) during the funeral and construction of the kurgan, and at the same time it may have helped protect the mound from natural erosion. Then, the whole mound was covered with loess material taken from a nearby pit.

7. The kurgans were located in an open area though surrounded by forests. This clearing may have been used earlier for pasture.

Acknowledgements. We dedicate this paper to the memory of the Prof. Kazimierz Klimek – our co-worker in the study of human-environment relations on the Kańczuga Plateau and the Prof. Jan Machnik – prominent researcher of barrows in the Carpathian and Subcarpathian regions. The research was conducted as TRAKT 66/99 and partly SUBIN 5/02 research projects for the Foundation for Polish Science (Maria Łanczont – head of projects). We would like to express thanks to Prof. Mirosław Makohonienko, Prof. Paweł Valde-Nowak, and Dr. Sergiy Telizhenko, for their insightful and valuable review comments, which significantly improved the quality of the manuscript. We also thank our colleague Dr. Artur Poręba for his involvement and help.

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