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The use of geological and geophysical methods to constrain the genesis of earth mounds at archaeological sites in the Jasło Foothills (south-eastern Poland)

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We show how geological and geophysical studies conducted in the Jasło Foothills, near Dukla, help constrain the genesis of two mounds, understood as heaped piles of earth, circular in plan view, located in Łęki Dukielskie (site 27 "Pod Kopcem") and Dukla (site 7). Eleven hand auger holes yielded sediment samples for grain size analysis by laser (with a Fritsch apparatus). Hand auger holes were also made at sites in Wietrzno-Sośnina (site 29), and in Łęki Dukielskie (site 5). Three of the mounds (Łęki Dukielskie sites 5 and 27 "Pod Kopcem", Wietrzno-Sośnina site 29) are revealed to be of natural origin, i.e. they are rock "lumps" covered with a thin layer of weathered silty-clay deposits. The fourth of the mounds (Dukla site 7) was found to have an anthropogenic origin; given its dimensions, it can be considered a late Neolithic Corded Ware kurgan. The geological analyses were complemented by GPR measurements, which supported the observations based on augering results.

Key words: Jasło Foothills, earth mounds, geological drilling works, GPR measurements.

INTRODUCTION

In the last few decades, several discoveries of kurgans, understood as burial mounds (anthropogenic embankments) erected on a circular plan, have been made in the Carpathian Foothills (Machnik, 1966). Excavations of some of these mounds have shown that they were erected over a long period of time, from the Neolithic to the Middle Ages (Gancarski and Machnikowie, 1986, 1990; Machnik and Sosnowska, 1996; Zoll-Adamikowa and Niżnik, 1963). Among the examples researched, which were supposed to represent earth mounds, some were found to be of natural origin, and so not related to intentional human activity (e.g., Janowski, 1963; Szałapata, 1963, 1964; Budziszewski et al., 2020). Thus, the identification of anthropogenic and prehistoric mounds and their separation from natural topographic features can be difficult.

In 2020, during surface archaeological studies in the Jasło Foothills, the genesis and geological structure of such mounds was investigated.

One such form can be found in Łęki Dukielskie, site 27 ("Pod Kopcem"), a second object is located in Wietrzno-Sośnina, site 29, and others are located in the forested area of the Łazy hamlet in Łęki Dukielskie, site 5, and in Dukla, site 7 (all sites are located in the Krosno district of the Podkarpackie voivodship). This paper is focused on two of these sites, Łęki Dukielskie (site 27, "Pod Kopcem") and Dukla (site 7).

METHODS

Six hand auger holes (diameter 5.5 cm) were drilled to identify the structure and genesis of the mounds. Four auger holes along a cross-sectional line were made in the village of Łęki Dukielskie (site 27) within one mound. Two auger holes were made into the mound described as Dukla (Łazy, site 7), whose anthropogenic origins raised no doubts.

During the fieldwork, macroscopic description of the sediments was made that included such lithological features as grain size, colour, organic matter content, consistency, plasticity and the presence of aggregates of marlstone pieces, carbonate concretions, charcoal and mineral clasts such as mica. At site 27, Łęki Dukielskie ("Pod Kopcem"), 26 samples were collected from fourauger holes. Fifteen samples were collected from auger hole no. 1 from the kurgan embankment at the

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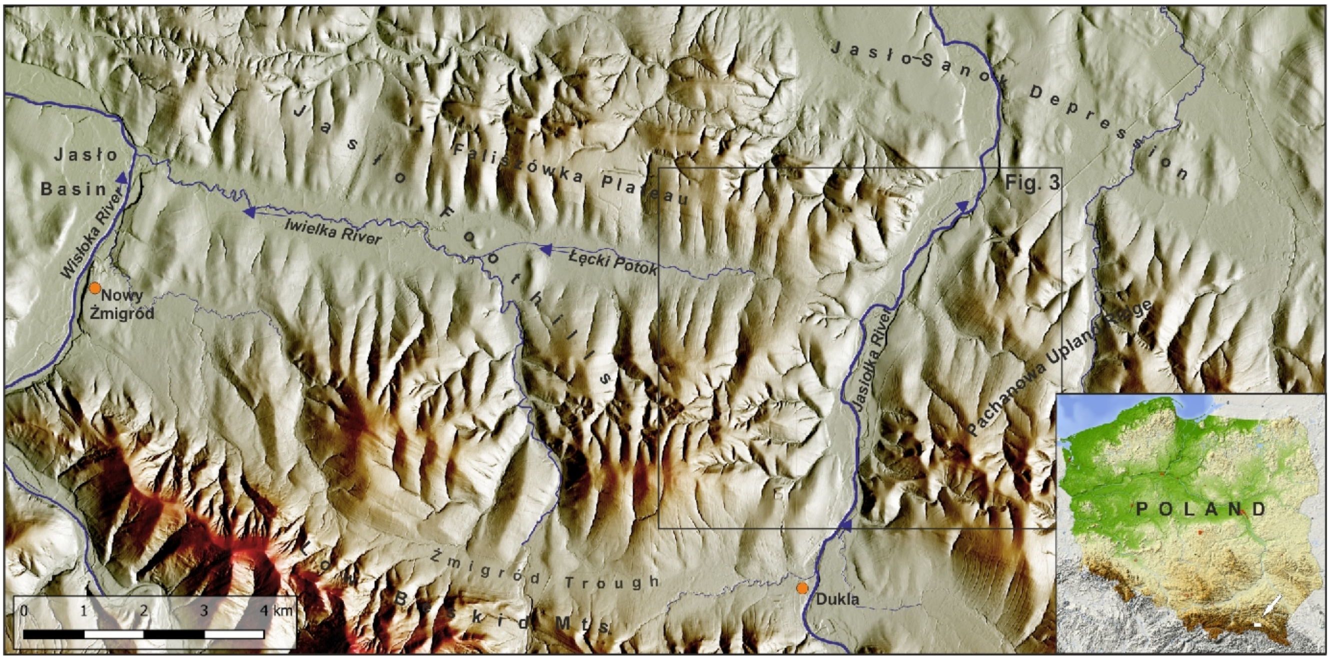

Fig. 1. Geomorphological regions in the area of Dukla and Nowy Żmigród (based on Starkel, 1972b and Gilewska, 1986)

Dukla (Łazy) site no. 7, nine of which were subjected to grain size analysis, performed using a laser method (with a Fritsch apparatus) for sediment samples which, after drying and grinding, were <1 mm in diameter. Samples containing a fraction >1 mm were subjected to sieve analysis. The particle size distributions are shown in Table 1 and the topographic plans and echograms in Figures 3–8.

The geological analyses were complemented with Ground Penetrating Radar (GPR) measurements performed along the auger hole section lines. GPR data were acquired using a Detector Duo GPR system, equipped with two 250 MHz and 700 MHz shielded antennae (see e.g., Rajchel, 2017, and Pasterkiewicz and Rajchel, 2017, for further details). This was to determine whether it is possible to identify the individual layers of particular geological formations and to obtain a more regionally based cross-section of the study area.

THE RESEARCH AREA – BRIEF OVERVIEW OF GEOLOGY AND GEOMORPHOLOGY

The research area with earth mounds is located in the Outer Flysch Carpathians, on the border of the Jasło-Sanok Depression and the Low Beskid Mountains (Starkel, 1972a; Figs. 1 and 2). According to the geomorphological division of Poland (Gilewska, 1986), this area belongs to the foothills of the Low Beskid Mountains, which includes the Jasło–Sanok Depression. The research sites are located in the southern part of the Jasło Foothills, north of the town of Dukla. Hydrographically, they belong to the Wisłoka River Basin (the subcatchment of the right-bank Iwielka River stream, the Łęcki Potok and the Jasiołka River). The Jasło Foothills, which form the southern part of Jasło–Sanok Depression, are divided into three smaller units: the Faliszówka Plateau and Pachanowa Upland Ridge, bordering the Low Beskids Mountains to the south, separated by the Żmigród Trough running latitudinally, which belongs to the Jasło Basin (Starkel, 1972b). To the east, the research area is limited by the Jasiołka Valley. On the General Geomorphological Map of Poland (Starkel, ed., 1980), the area in the southern part of the Jasło Foothills is characterized by even ridges and hummocks with preserved elements of an older topography: the foothill level. The highest peaks on the ridge, extending south of Łęki Dukielskie, reach a height of 534 m a.s.l. (Franków Mountain), while in Łęki Dukielskie and in the Wietrzno area, the heights of the peaks drop to 400–433 m a.s.l. The bottom of the Łęcki Potok Valley is at an altitude of 320–340 m a.s.l., and the bottom of the Jasiołka Valley is 310 m a.s.l.

In the bedrock of the Quaternary formations in the research area, rock units belonging to the Dukla and Silesian nappes of Cretaceous–Paleogene age are found (Jankowski and Kopciowski, 2006; Fig. 2). These rocks are represented predominantly by less resistant shales and thin-bedded sandstones, as well as thin- and medium-bedded sandstones and shales of the lower Krosno layers (Jankowski and Kopciowski, 2014). The hills are formed by thick-bedded sandstones and shales of the lower Krosno beds, as well as shales, sandstones, cherts and marls ascribed to the menilite layers, which are more resistant to weathering and erosion. Sandstones are usually grey in colour, they weather easily, are calcareous and contain, in addition to quartz, common mica flakes.

Morphotectonically, the research area is located in a longitudinal tectonic depression, i.e. the Central Carpathian Depression (Świdziński, 1953). Several folds developed in the form of overlapping tectonic slices, such as the Osobnica-Bóbrka-Rogi fold with a NW–SE trend, may be found in this region. The southern limb of the fold dips to the SW and its northern limb is faulted. To the north of the Dukla and Magura nappes, the Nowy Żmigród–Iwonicz–Rudawka Rymanowska tectonic slice can be seen in the research area.

Quaternary deposits overlie the flysch, in units of varying thickness which are diverse in terms of genetics, lithology and age. The largest study area within the hummocks and slopes of the valleys is occupied by weathered loams (Łęki Dukielskie area) and loam with slope rubble (solifluction-prolluvial) as well as loess and loam deposits of aeolian origin (Wietrzno area) (Wójcik, 2003). On the slopes of the valleys, there are places

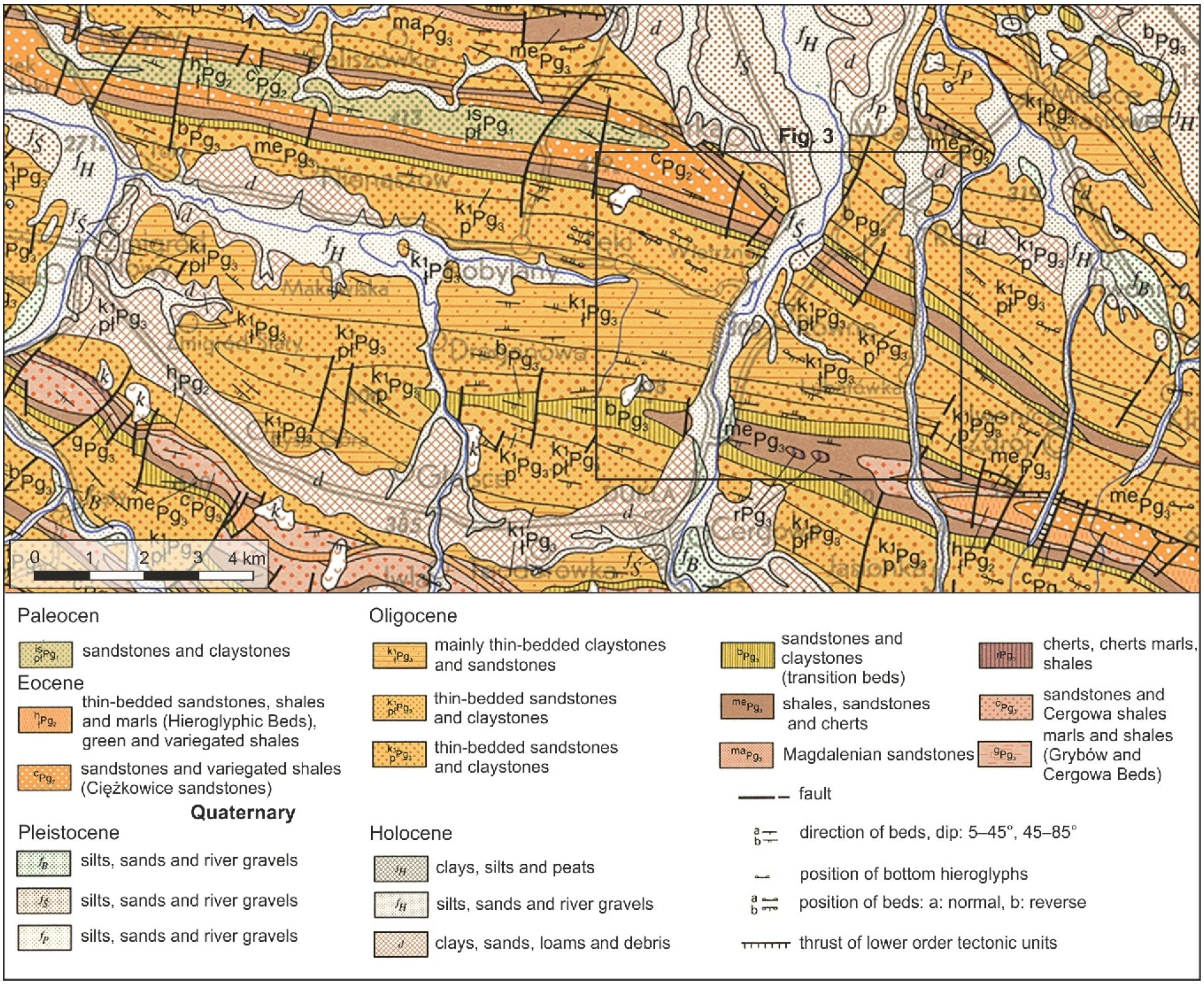

Fig. 2. Geological map of the substrate to the Quaternary deposits (after Rączkowski et al., 1992)

Table 1

Results of grain size analysis, Dukla (Łazy), site 7

Sample	Depth [cm]	Grain size [mm]				Folk Warda Method [phi]			
		2.00–8.00	0.125–2.00	0.002–0.125	poniżej 0.002	MEAN	SORTING	SKEWNESS	KURTOSIS
D 1	18–22	0	11.02	73.79	15.2	6.500	2.523	–0.214	0.942
D 2	45–50	0	8.6	75.59	15.8	6.819	2.335	–0.220	1.073
D 3	86–90	2.13	3.99	77.5	16.39	7.178	2.105	–0.198	1.218
D 4	108–112	0	3.74	75.28	20.99	7.606	1.771	–0.094	1.042
D 5	140–144	0	4.92	79.96	15.12	7.030	2.016	–0.112	1.037
D 6	159–163	0	5.01	78.89	16.1	6.990	2.100	–0.127	1.030
D 7	163–167	0	7.56	79.07	13.37	6.595	2.236	–0.088	1.012
D 8	170–173	0	4.88	80.66	14.44	6.785	2.120	–0.075	0.989
D 9	180–183	0	12.99	75.15	11.86	6.065	2.491	–0.088	0.858

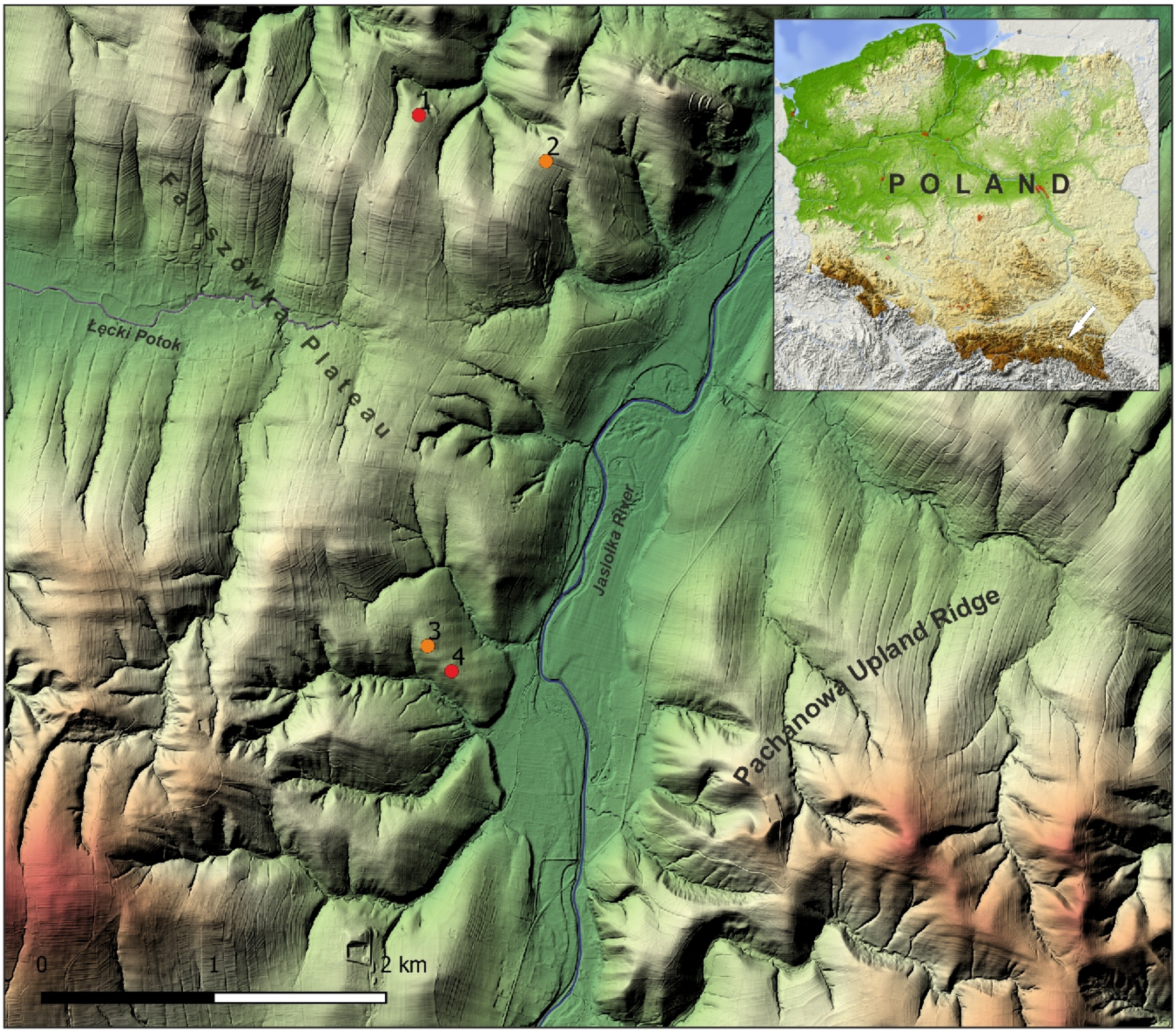

Fig. 3. Location of earth mounds included during archaeological research

1 – Łęki Dukielskie, site 27, "Pod Kopcem"; 2 – Wietrzno (Sośnina), site 29; 3 – Łęki Dukielskie (Łazy), site 5; 4 – Dukla (Łazy) site 7; red dots mark the sites described in detail in the text

with landslide colluvia marked on the geomorphological map of the SMGP (Jankowski and Kopciowski, 2006). The bottoms of the valleys are built of loams, clays with an admixture of sands (muds) as well as sands and gravels of fluvial terraces and floodplains.

GEOMORPHOLOGICAL CHARACTERISTICS OF THE RESEARCH SITES AND GEOPHYSICAL, AND GEOLOGICAL RESULTS

ŁĘKI DUKIELSKIE, SITE 27 ("POD KOPCEM")

The mound selected for the research is located at an altitude of 387.9 m a.s.l., on the ridge flat within the lower part of a slope facing north-east (Figs. 3 and 4). The ridge flat with a slope of 5–6° is one of the arms of the elevation culminating at an altitude of 419.4 m a.s.l. The mound is approximately oval in shape, ~40 m in diameter and 3 m in relative height. It descends to the south-west with a gently descending (of a few degrees) slope, and is limited by a steep slope to the north. In the geological profile, at a distance of 20 m from auger hole no. 1 and ~2 m below the top of the mound, there is a clear slope foot, cut by a V-shaped valley. The 4 auger holes drilled along the cross-sectional line (Fig. 5) illustrate the morphology and internal structure of the mound and the under-slope flattening, and constitute the basis for determining the genesis of both forms. Auger hole no. 1, located at the top of the mound, revealed the presence of sandy silt with fragments of sandstone, belonging to the weathered sandstone substrate of the lower Krosno beds beneath the soil at a depth of 21–75 cm. Borehole no. 2, located on the slope of the mound, showed that the mound is made of a thin layer of silt with sandstone debris, 51 cm thick, similarly to auger hole no. 1.

In auger hole no. 3 located at the foot of the mound, the thickness of the loam deposits penetrated is 160 cm. Beneath the soil, at a depth of 24–90 cm, there is grey-yellow clayey silt, and ash-yellow sandy loam with mica from 90 to 118 cm. In the

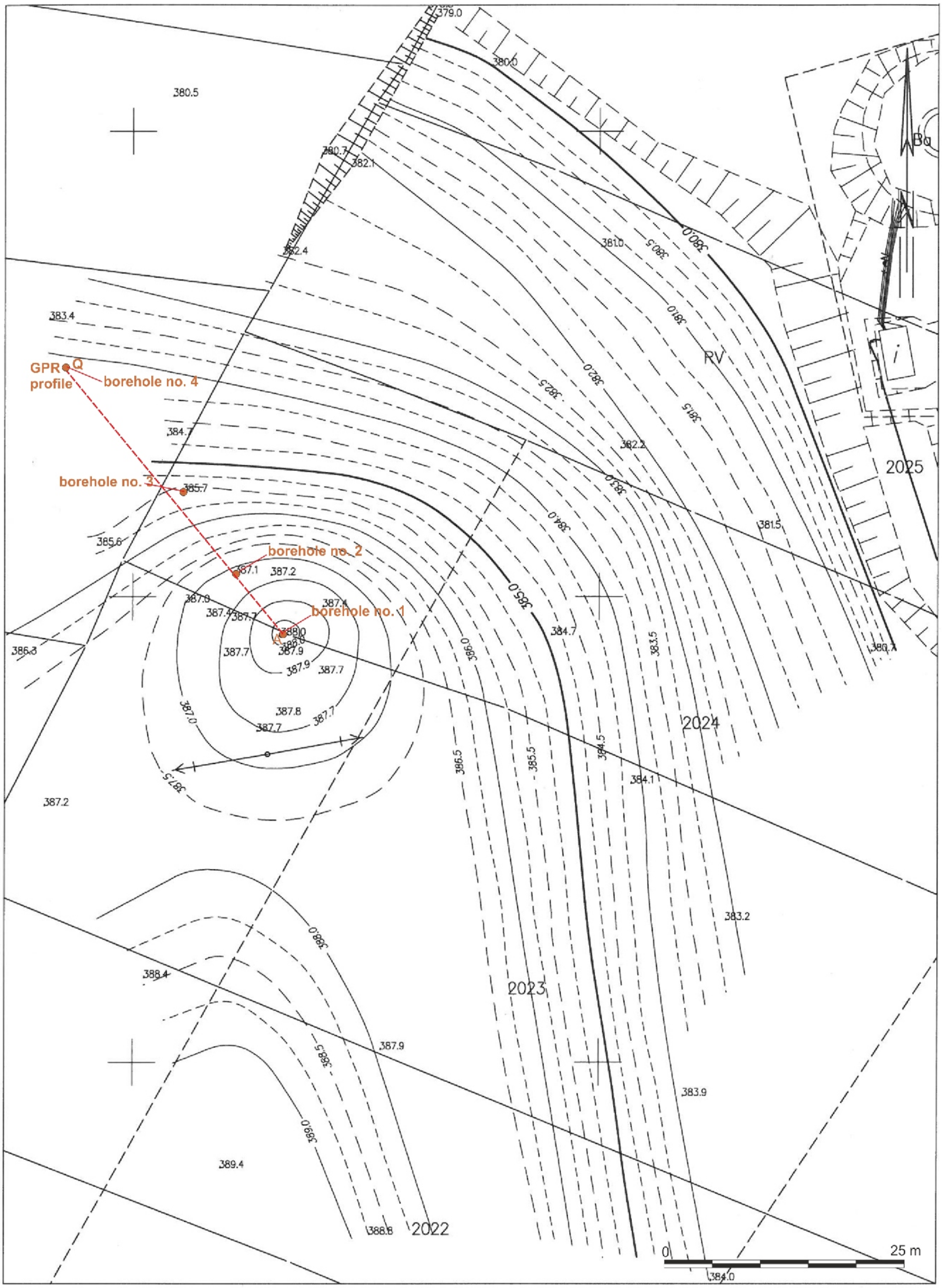

Fig. 4. A topographic plan of the earth mound showing location of auger holes and GPR profile, Łęki Dukielskie, site 27 ("Pod Kopcem"), Krosno district

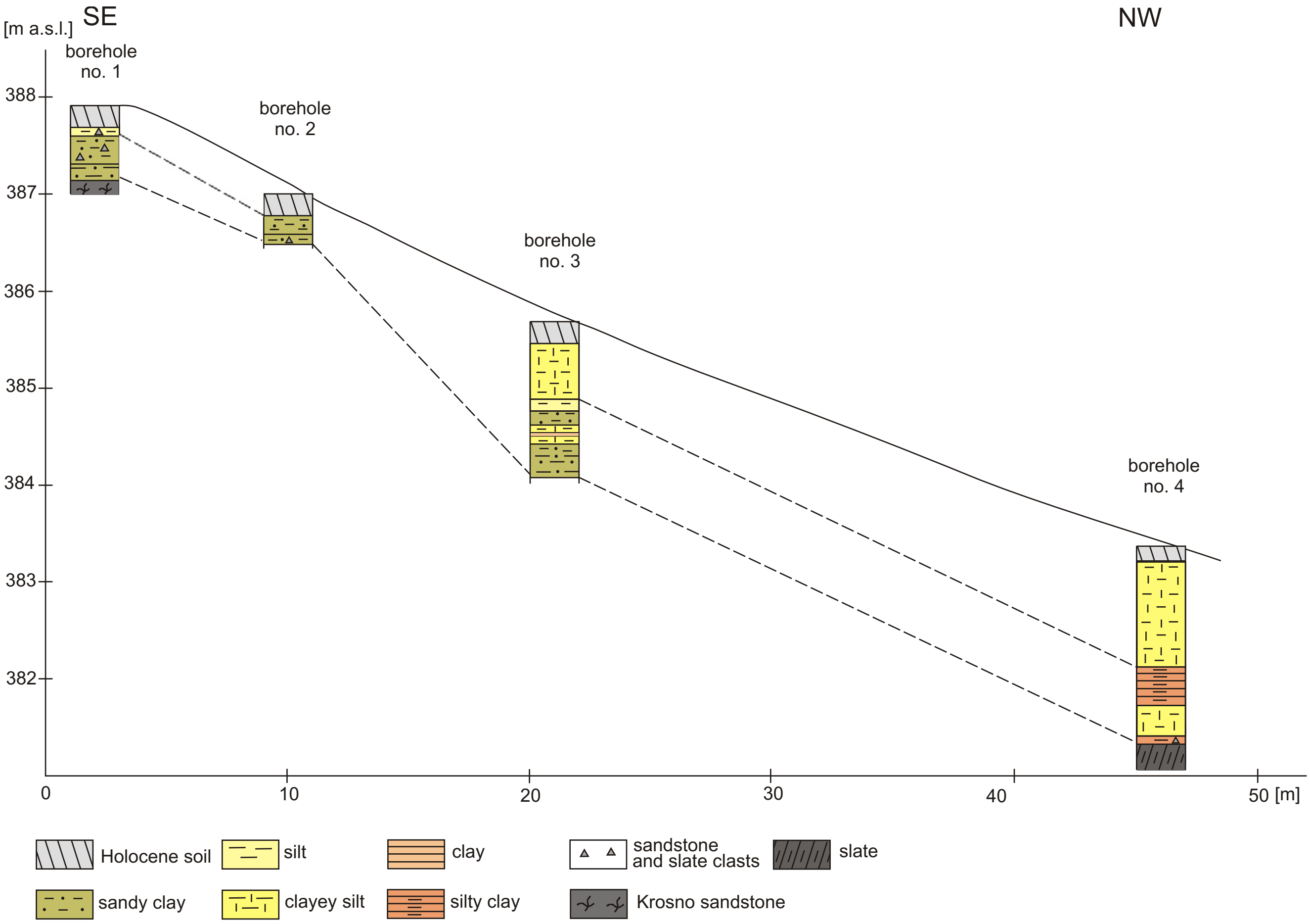

Fig. 5. Geological cross-section of the mound at site no. 27 in Łęki Dukielskie

bottom of the profile from 118–136 cm, there is clayey silt with an admixture of sand and sandy clay from 136–160 cm.

In auger hole no. 4, the succession penetrated is 230 cm thick. In the top of the sequence below the soil at a depth of 17–127 cm, there is slightly clayey ash-grey loam, which changes its colour at a depth of 45 cm to ash-yellow and transitions into silty clay (127–164 cm). Yellow-ash clayey loam transitioning into silty clay with fragments of weathered slate (transition layer at a depth of 200–206 cm) and a flysch substrate made of grey-black slate at a depth of 206–230 cm prevail in the bottom of the sequence, at a depth of 164–200 cm. The auger holes showed that the layer of loams (clay) deposits, which builds the mound near the wind power plant, originated by weathering. At the culmination of the mound, beneath the weathered loams with sandstone fragments with a thickness of 0.5–0.7 m, there is bedrock (flysch sandstone).By contrast, on the under-slope flattening below the mound, the thickness of loam deposits increases to 1.6 m, which is likely the result of overlapping of slope (prolluvial) or aeolian sediments onto the weathered rocks. The nearest exposure of loam with rock rubble on the slope of the eastern exposure was described in the village of Wietrzno at Jasiołka River (Wójcik, 2003). However, the small thickness of the layers at the foot of the mound and the similarity in grain size of the sediments with the rocks forming the bedrock (e.g. slates in auger hole no. 4 and the loam layers developed on them) suggest that the sediments described are weathering products. The map of Quaternary formations in the Jasło Foothills in the area of Wietrzno, Rogi and Równe is dominated by weathered loams and loams of "various genesis" (Wójcik, 2003). However, in the explanations of the Nowy Żmigród 1:50,000 sheet of the Detailed Geological Map of Poland, sandy loams and silts, less often clay sediments of weathered, slope and aeolian origin fall within one common subdivision: loess-like loams and silts and weathered silts, colluvial and aeolian silts (Jankowski and Kopciowski, 2014). These 1–2 m thick layers composed of weathered loams and related sediments are not distinguished by geologists on 1:50,000 geological maps, where outcrops of flysch rocks are shown.

GPR data were acquired along the NW–SE section line defined by the four auger holes. A number of minor anomalies were found in the recorded echogram (Fig. 6). Most of these reflect the geological units encountered during the research. Around auger hole no. 4, at a depth of 0.50 / 0.70 - 1.70 m, there is an anomaly that may originate from the loam layer. Additionally, along the section line from 0.0 m to ~44.0 m, at a depth of ~1.70 m to 2.30 m, a horizontal anomaly originating from the rocky geological substrate (slate) is evident. The flysch sandstones found in borehole no. 4 are inferred to be present at this depth. They can be seen in an exposure located in the immediate vicinity of the mound.

DUKLA (ŁAZY), SITE 7

The kurgan in Dukla (Łazy), marked as site 7, is located in the forest on a broad ridge flat, which gently slopes towards the south-east (Ginalski and Muzyczuk, 1993; Figs. 3 and 7). The

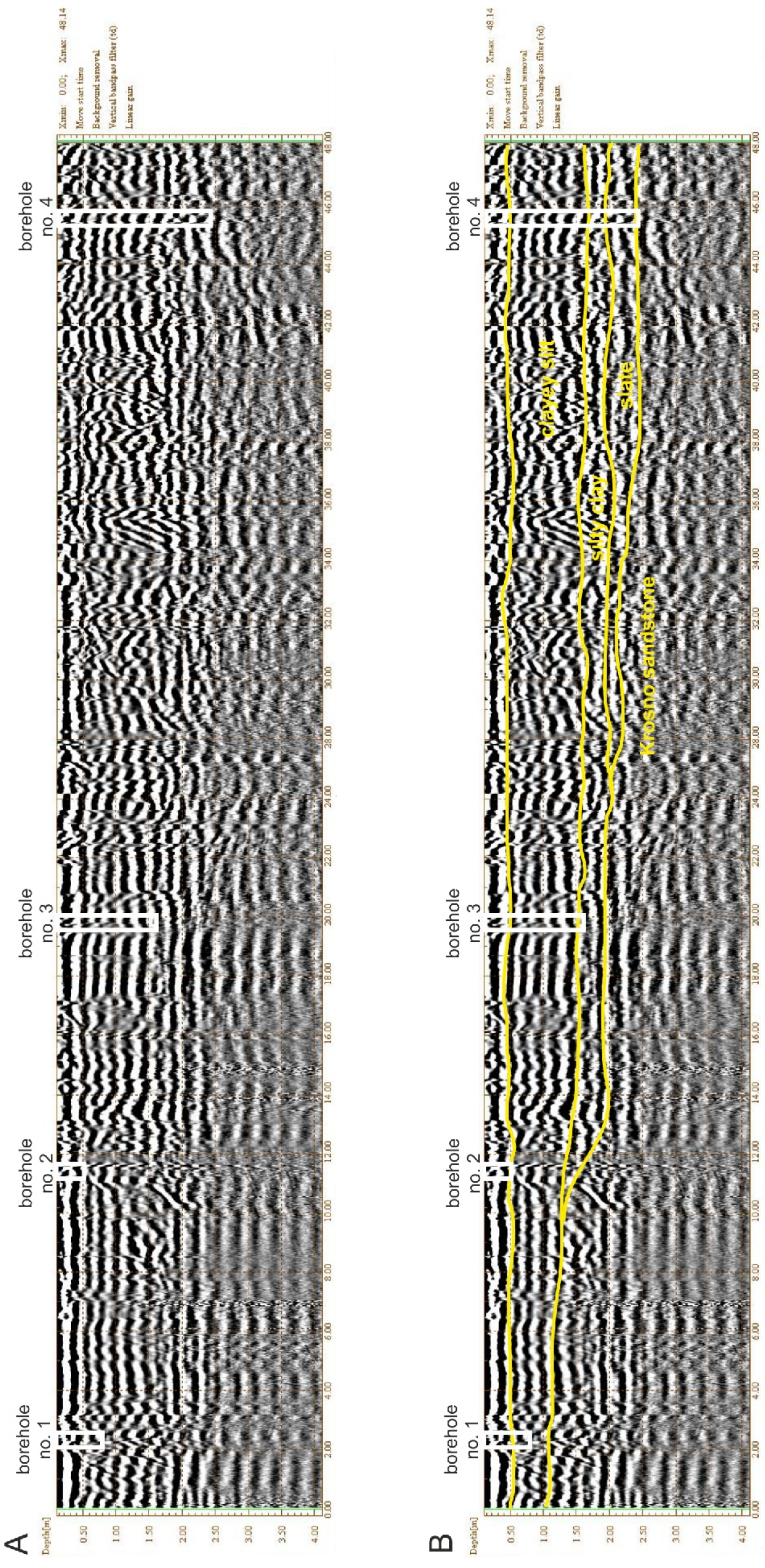

Fig. 6. Echogram from the AQ profile showing locations of auger holes (A) and interpretation (B), Łęki Dukielskie, site 27 ("Pod Kopcem"), Krosno district

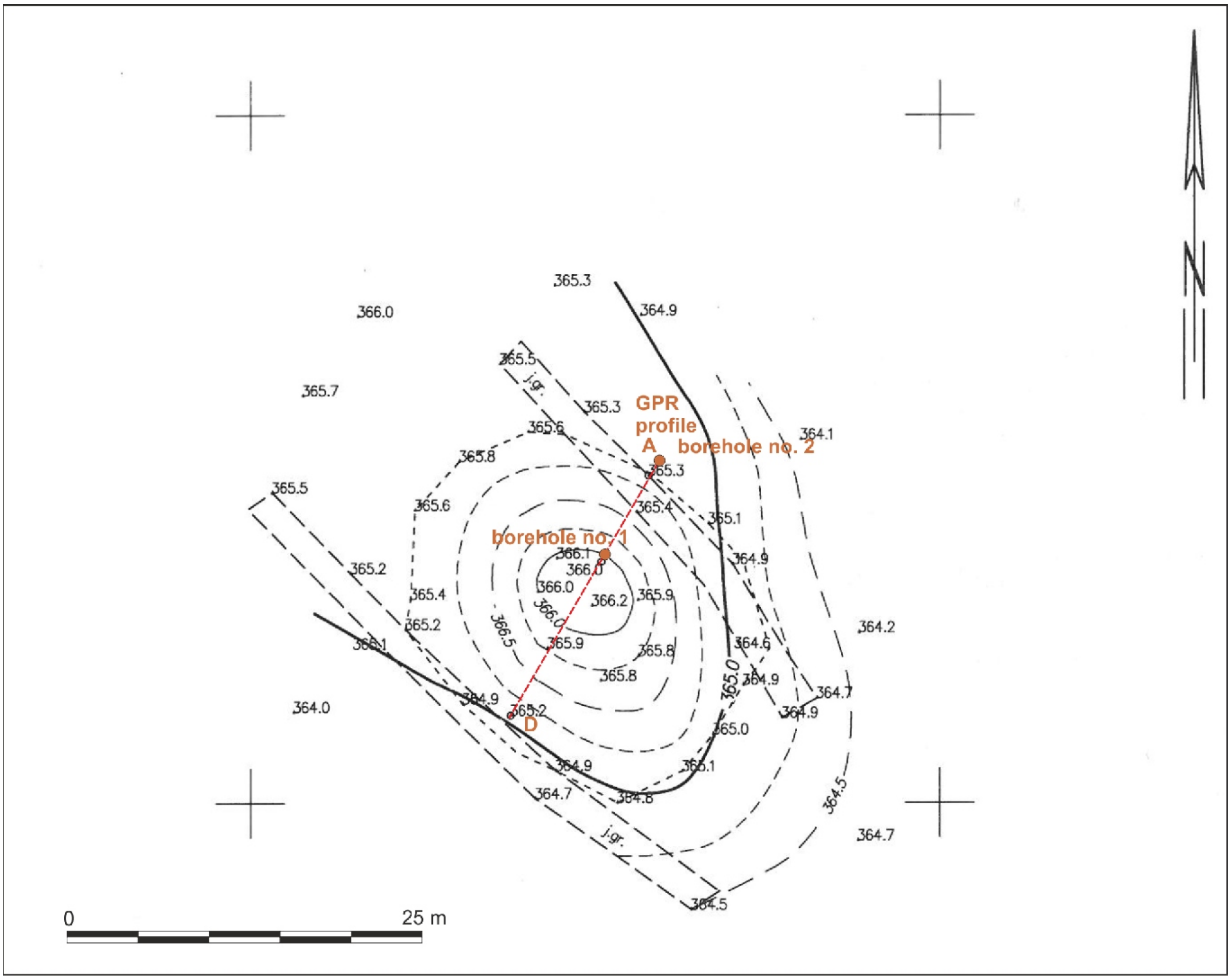

Fig. 7. Topographic plan of the earth mound showing locations of auger holes and GPR profile, Dukla (Łazy), site 7, Krosno district

broad ridge is limited by the steep slope of a V-shaped valley (Jasiołka tributary) to the south-west, and by a gently falling slope of the Jasiołka valley to the east.

The kurgan is located 365.9 m a.s.l., i.e. 55–56 m above the Jasiołka River. Based on geodetic measurements, the relative height of the feature was estimated at 1.2 m, with a diameter of ~20 m (Fig. 6). Auger hole no. 1, drilled below the culmination from the NW side of the top of the kurgan, documented lithologically diverse sediments and the presence of several layers of both natural and anthropogenic genesis (Fig. 8).

Below the soil, at a depth of 30–75 cm, there is grey-yellow silty loam transitioning into more dense light-brown clayey silt to a depth of 105 cm. At a depth of 105–136 cm, there is a clay, a gleyed level with vertically developed grey structures, probably root remnants. Below it there is grey clayey silt with dark black aggregates of humus and grey clay material (136–150 cm), overlying a layer of silty loam with white fragments of marl? (150–163 cm), and charcoal clusters at a depth of 163–167 cm. The bottom of the profile at a depth of 167–183 cm is made of grey silty, relatively loose clay with white calcium carbonate (or marl?) fragments and many flakes of mica.

Nine samples were collected from auger hole no. 1 for grain size analysis. The results of the analyses enabled detailed description of the layers identified and determined which of them are of natural origin and which are the result of human activity. Deposits up to a depth of 136 cm show gradual fining towards the bottom, which is marked by an increase in grain size (Mz from 6.5 to 7.6 phi; Table 1). Such a grain size distribution may indicate the prevalence of eluviation and illuviation processes in the soil profile. This is consistent with the increase in the colloidal clay fraction (<0.002 mm) in the lower part of the layer analysed (Table 1). The sediments at a depth of 136–173 cm are characterized by a wide range in grain size and Mz = 6.6–7.03 phi. However, the deposits at a depth of 173–183 cm contain the largest sand content (0.125–2.0 mm), amounting to 13%, indicating the presence of sandstone detritus at the bottom of the burial mound. Based on the macroscopic description of the sediments and the results of grain size analyzes, three units in the mound's profile can be distinguished (Fig. 8).

The first upper unit involves the natural profile of the Holocene soil, in which several genetic levels altered by soil-forming processes can be distinguished (including a level of humus accumulation with modern plant roots, a level of washing and a clay-loam level of gleying). This soil was formed within the kurgan embankment and developed from the moment it was erected and covered with vegetation. The second (middle) unit consists of clayey loam and silty grey deposits with an admixture of humus, carbonate fragments (marl?), and dark layers

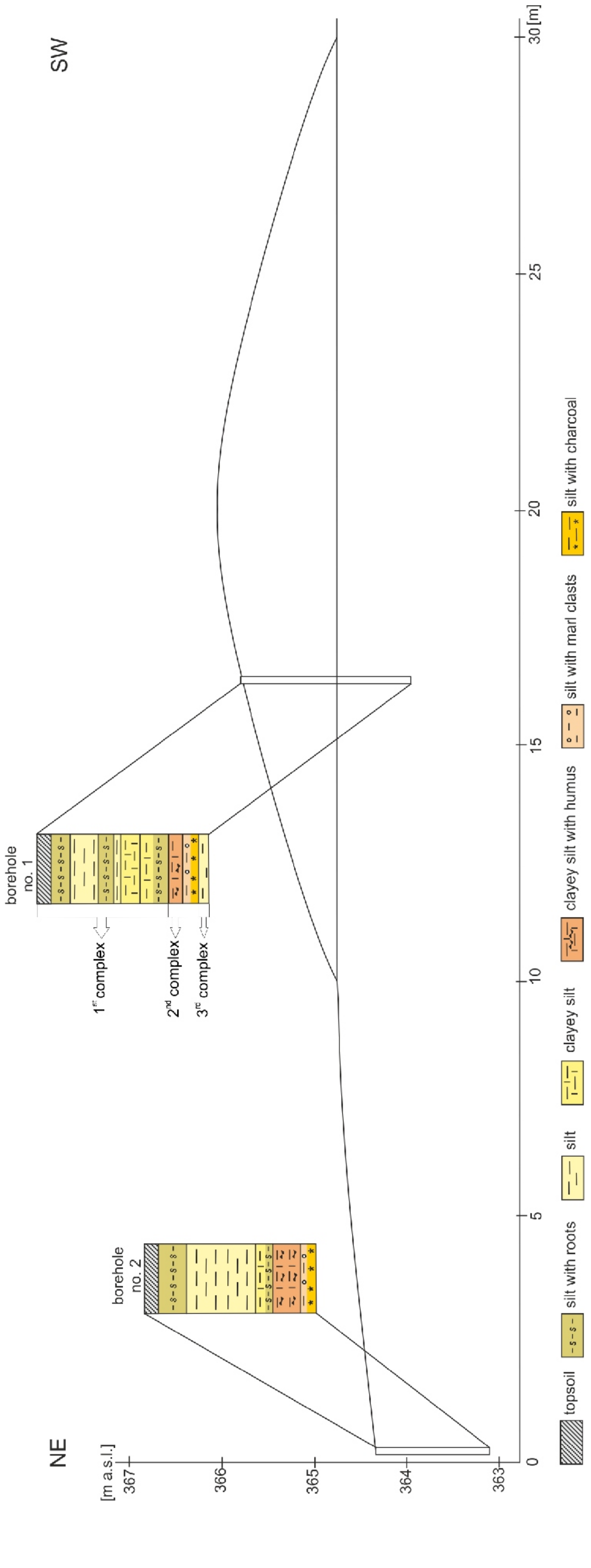

Fig. 8. Profiles of the layers of the burial mound in Dukla (Łazy), site 7 based on auger holes 1 and 2

with charcoal. These are anthropogenic layers, which probably developed as a result of collecting plants and soil burnt out after fire by people who later used this material to build the kurgan. The third, bottom unit is grey/ash silty loam with many mica flakes. This is weathered loam constituting a natural substrate on which the kurgan was built. The structure of the soil profile is similar to the profiles of kurgans erected by the Neolithic people of the Corded Ware culture in Bierówka on Garb Warzycki (Gancarski and Machnikowie, 1986; 1990; Kornornicki et al., 1990). Embankment layers from similar times are shaped in a similar way, e.g. in the Ondavská Upland, on the Slovak side of the Carpathians (Gerlach, 2008; Machnik et al., 2008).

GPR confirmed the heterogeneity of the internal structure of the mound recorded in the borehole profiles (Fig. 9). Beneath a layer of humic soil, clusters of anomalies are visible, the depth and extent of which can be fairly well traced. They are associated with accumulation on the primary surface of the artificial embankment at a depth of up to 1.5 m. A continuous undisturbed layer runs at a depth of 1.5–2 m, clearly distinguishable from the top zone (embankment). This can be assumed to represent a layer of bedrock (sandstone). Furthermore, there is a visible contrast at the boundary between anthropogenic layers and intact zones.

CONCLUSIONS

The auger holes revealed that at site no. 27 in Łęki Dukielskie and in Wietrzno-Sośnina (site 29), convex landforms located on the ridge flats are of natural rather than anthropogenic origin. These are "bumps" of the Krosno sandstone covered in a thin layer of weathered clay. The mound at site no. 5 in Łęki Dukielskie (Łazy) should be interpreted similarly. The auger hole made into the mound in Dukla (Łazy), site 7 penetrated several layers of loam (clay) sediments beneath the soil containing, humus aggregates and charcoal, which confirm their anthropogenic genesis. These observations were supported by GPR profiles. It is shown that these topographic are geologically varied. The analyses also showed the structure of the deeper geological layers and precisely defined the level of the rock layer. However, it is impossible to define internal structures and boundaries between geological layers based on GPR data alone. The geological and GPR results from these archaeological sites have shown the utility of both methods for constraining the genesis of earth mounds located in this region.

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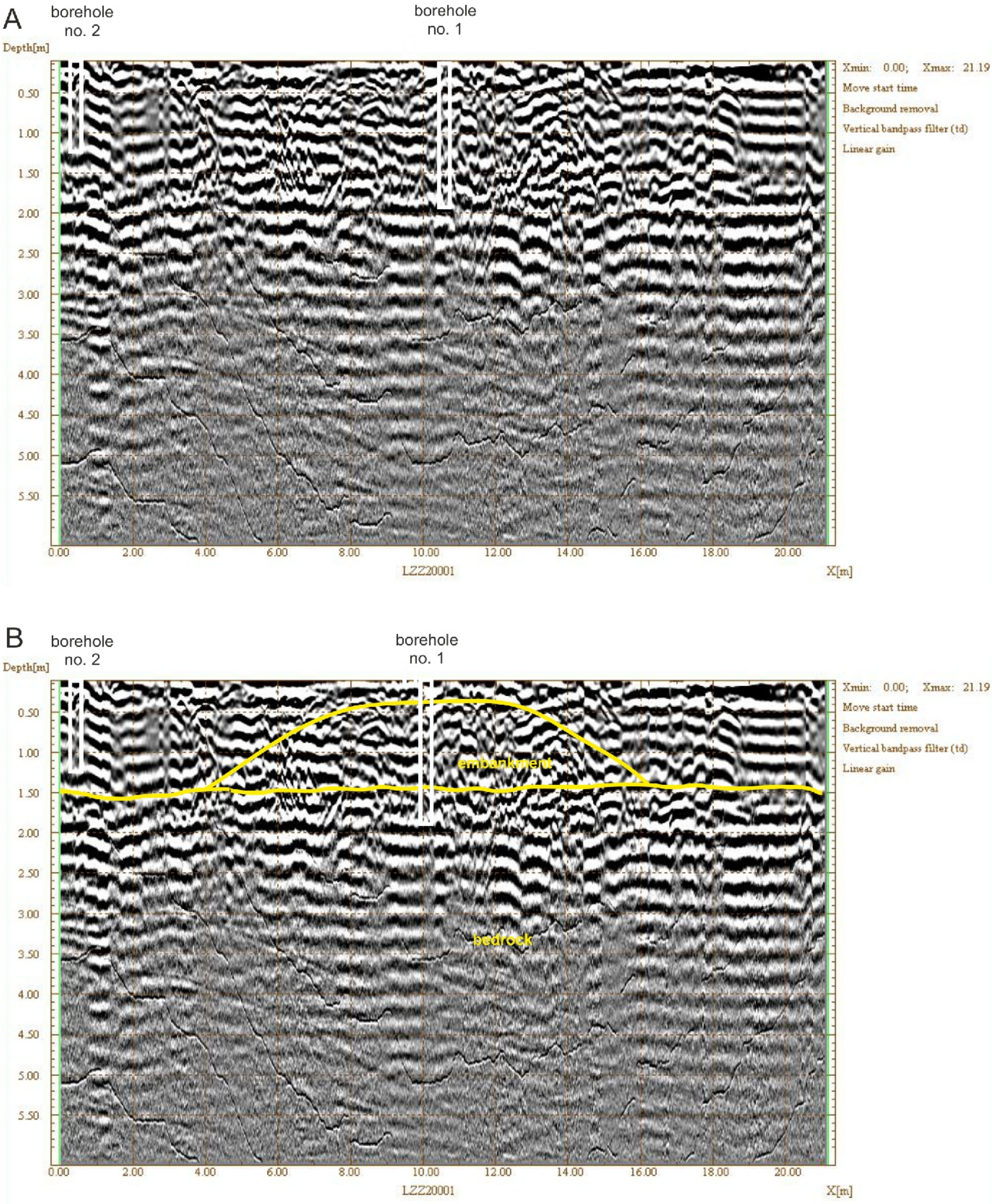

Fig. 9. Echogram from the AD profile showing locations of auger holes (A) and interpretation (B), Dukla, site 7 (Łazy), Krosno district

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