An Early Neolithic House in the Foothills: A Case Study of Pottery and Lithic Artefacts from the Biskupice Site 18 (Wieliczka Foothills, Southern Poland)

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Abstract

The paper presents a comprehensive analysis of pottery and lithic materials found in archaeological features associated with an Early Neolithic house from Biskupice (southern Poland) to shed light on exchange networks of the first farmers in Central Europe. **The research began with the discovery of a unique fragment of a face vessel made in the Želiezovce style, a motif primarily found in Moravia and north-eastern Austria. Therefore, specialised analyses were undertaken to determine whether the Biskupice fragment was locally produced or originated from areas south of the Sudetes and Carpathians.** The study involved an examination of raw clay material and the technology used to create the anthropomorphic vessel, aiming to establish its provenance (local production *versus* import). Petrographic methods were employed to analyse a diverse group of vessel types for comparison. Additionally, a selected group of pottery fragments, including the face vessel, underwent lipid residue analysis to determine their potential use. The combination of microscopic examinations and lipid residues analysis was utilised to study the link between the physical properties and function of the vessels. Finally, the archaeological context of other artifacts from the same house, including lithic assemblages, was investigated to determine the presence of both local and imported raw materials in Biskupice. The main conclusion of the study indicates local production of pottery, including the face vessel, and lithic implements. Conversely, a Transcarpathian transfer of some technological and decorative ideas, as well as imports of raw material such as obsidian, were confirmed.

Keywords: Linear Pottery culture, Early Neolithic, Želiezovce phase, petrographic analysis of pottery, lipid residue analysis, lithic analysis

1. Introduction

During archaeological excavations conducted in 2020 in Biskupice, southern Poland, a vessel depicting a human face with horn-liked protrusions was discovered in a feature associated with a house belonging to the Linear Pottery culture (abbreviated as LBK, from

German *Linearbandkeramik*). This archaeological unit is roughly dated to the second half of the sixth millennium BC. Anthropomorphic vessels and figurines referred to the Early Neolithic in Poland are extremely rare (Czerniak, 1998, fig. 6; Dębiec, 2014; Czekaj-Zastawny, 2014, fig. 39), making this find particularly noteworthy. The stylistic motifs of the vessel from Biskupice were already analysed taking into account all other human representations from European LBK sites and those coming from the Alföld Linear Pottery culture. The comparison of 130 face vessels revealed a strong connection between the pot from Biskupice and the Želiezovce style, typical of the late phase (III) of LBK (Korczyńska et al., 2021). The Želiezovce style is primarily found in south-western Slovakia, where a separate Želiezovce group or even culture was distinguished, divided into phases and subphases (as Želiezovce I, IIa, IIb and III; Pavúk 1969; 1994). In Poland, it is territorially limited mainly to the Upper Vistula River Basin (Czekaj-Zastawny, 2017) including the Carpathian Foothills (Valde-Nowak, 2014; Czekaj-Zastawny et al., 2021). Therefore, this new find from Biskupice indicates chrono-cultural connections with areas located south of the Carpathians.

The artefact in question was discovered in feature no. 25, which is part of the well-preserved house no. 2. This long house with a post construction is typical of the LBK. The exceptional nature of the face vessel finding prompted the research team to attempt to analyse and interpret in detail its archaeological context, i.e., house no. 2, before completing a comprehensive investigation of the entire settlement. Therefore, this study only presents the analysis of the features and materials found in one of four possible houses discovered during recent excavations in Biskupice. Additionally, there is evidence of another house of the same chronology found on the highest part of the elevation on which the settlement was situated. It was excavated partially for rescue reasons before 2020 (Czerniak, 2014, unpublished). Currently, the settlement is divided by a road and therefore, it is impossible to trace a relationship between house no. 2 and other household units, the internal organization of the settlement and the chronology of all the households. The full extent of the settlement is difficult to evaluate due to the unsuitability of non-destructive methods due to the characteristics of the soil condition and the presence of modern buildings in the north-western part of the site (Moskal-del Hoyo et al., 2022, unpublished). Early Neolithic artefacts found during the surface survey suggest that this area may not have been very large, between 0.5 and 1 hectares. Nevertheless, based on the local geomorphology and current field research, it is likely that the settlement was composed of a small group of households.

Archaeological settings

The site at Biskupice is situated on a loess-mantled hummock (approximately 312 m.a.s.l.), delimited by two streams (Korczyńska et al., 2021). **It is located in the Wieliczka Foothills, which belong to the belt of Carpathian Foothills (Kondracki, 1998). The site is part of the Early Neolithic settlement zone in southern and south-eastern Poland, specifically within the settlement cluster connected with the loess landscapes in the Upper Vistula River Basin (Fig. 1; Czekaj-Zastawny, 2009). These landscapes also cover regional sections of Carpathian Foothills (Fig. 1; Valde-Nowak, 2014; Czekaj-Zastawny et al., 2020).** The site was identified through systematic field surveys (the Polish Archaeological Record; in Polish: Archeologiczne Zdjęcie Polski, abbreviated as AZP), but the first remnants of LBK settlement appeared during a rescue excavation (Czerniak, 2014, unpublished). The unique location of the LBK site in the foothill zone was one of the significant factors that led to the initiation of new excavation works in 2020. Another noteworthy feature of the site, confirmed by the excavation, was the presence of materials typical of only one occupation phase (LBK), providing optimal conditions for a case study on Early Neolithic occupation. This approach helps avoid the problems of post-depositional disturbances and mixing of archaeological materials that typically occurs in multiphase sites.

During two archaeological campaigns (2020 and 2021), remains of at least four LBK household units were uncovered (Fig. 2). Only one of the houses – house no. 2 – was discovered in its entirety. Its remains included 37 remnants of posts arranged in five rows and four lateral pits. Two of the pits were located along the western wall (features nos. 23 and 24), and two were localized along the eastern wall (features nos. 20 and 25). The house was oriented on a north-south axis, and its size might be estimated at approximately 6 m x 11 m. All four elongated pits, situated outside the outer walls along the longer axis of the house, had oval, orthogonal shapes. Their dimensions varied between 1.2 – 2.2 m on the longitudinal axis and 2.7 – 4.3 m on the later axis, with maximum depths ranging from 0.35 m, to 0.9 m (Fig. 3). All four were characterized by irregular bottoms, and their fill contained a sequence of loessic inclusions and cultural layers that differed in colour and consistency of the sediment. Considering the division proposed by P. J. R. Modderman (1986, Fig. 29), this house represents Type 2 (with one corridor on the north side). This type of relatively small house is not typically discovered at LBK settlements, although a similar construction was detected at the site Brzezie no. 17, a few kilometres northeast of Biskupice (Czekaj-Zastawny, 2009; Czekaj-Zastawny, 2014).

All the elongated pits yielded pottery fragments, flints, obsidians and some small daub fragments (Fig. 4, Table 1S). As mentioned earlier, the most spectacular finding associated with this house is the face vessel deposited in the elongated pit no. 25 (Korczyńska et al., 2021). In addition, this pit contained 408 mostly undecorated pottery sherds, as well as 368 flint and three obsidian artefacts. The proportions of various types of findings are quite similar to other elongated pits connected to this house, with an exception of feature no. 20, located north to the pit no. 25, which delivered many more lithics, mostly chips. Additionally, two fragments of querns appeared in this feature (Table S1).

In the northern part of the house no. 2, two further pits (features nos. 18 and 22) were discovered. Both had circular, orthogonal shape of approximately 2 m in diameter and elliptical cross-sections. In general, their fill was characterized by a dark-brownish colour. The taphonomy of the sedimentation of both differed from the elongated pits. In the case of feature no. 18, the fill was relatively homogenous. In contrast, the fill of feature no. 22 was clearly laminated, and there were a few stones with signs of heat exposure found within one of the layers. In comparison to the elongated pits, the proportions of the particular types of artefacts differed significantly (Fig. 4, Table 1S). It is challenging to discuss the function of these pits and their chronological relation to the house no. 2. Due to the location of pit no. 22 within the house no. 2, it is presumed that both structures could not be contemporary. On the other hand, the function of feature no. 18 such as a storage pit, cannot be ruled out since this relatively shallow pit contained the highest number of charred plant remains, mostly cereals (Kapcia et al., 2023). Whether this pit was serving the community that lived in house no. 2 remains an open question.

Aims of the study

The specific objectives of the research were, firstly, to provide new AMS dating of the Želiezovce style represented in the Biskupice site. The chronological framework of this phase in Poland is not well established due to a scarcity of archaeological sites with reliable series of radiocarbon datings (Oberc et al., 2022). In south-western Slovakia, the absolute chronology of the Želiezovce phenomenon as a whole, as well as its traditional stylistic sub-phases, is also imprecisely defined, and there is uncertainty of its status (group?,

culture?, style?). Secondly, the aim was to determine whether the face vessel from Biskupice represents an import from areas south of the Sudetes and the Carpathians or if it was produced locally. To achieve this goal, the clay raw material and the technology of this pottery fragment were analysed. An important question concerned its function, which was tested with the help of lipid residue analysis. Similar analyses were performed on pottery sherds found in features connected with the same house to provide a context to this exceptional finding. Thirdly, the study aimed to discern further determinants of the Transcarpathian contacts, through analyses of the pottery and lithic artefacts.

2. Materials and Methods

2.1. Radiocarbon dating

A total of 10 samples for radiocarbon dating were selected from features associated with house no. 2. They consist of charred plant macro-remains obtained from archaeobotanical samples collected during the archaeological excavations. For each dating result, one taxonomically identified cereal grain was chosen, considered relevant for obtaining the most accurate dating result (Nowak et al., 2017), from a sample taken from a deep layer of each archaeological feature. Cereal caryopses (n = 9) belonged to emmer wheat *Triticum dicoccon* and/or einkorn wheat *T. monococcum* (Table 1). Additionally, one sample comprised 3 fruits of wild buckwheat *Fallopia convolvulus* (Table 1) as this species is one of the most frequently found wild herbaceous plants at this site (Kapcia et al., 2023) andcould have been used as food. For dating, accelerator mass spectrometry (AMS) at the Poznań Radiocarbon Laboratory was employed, following the methods of chemical pre-treatment (Brock et al., 2010). Calibration was made using OxCal ver. 4.4 (Bronk Ramsey, 2009) with 14C calibration curve IntCal20 (Reimer et al., 2020).

2.2. Pottery

The analysis of pottery fragments was conducted through measurements of their dimensions and weight, along with a description of their state of preservation, technology (evaluated macroscopically), forms, and decoration. The distribution of all pottery sherds found in the features associated with house no. 2 took into account the three-dimensional location of all fragments, which was fixed using a Total Station (model Geomax Zoom 40).

2.2.1. Petrography

A total of 27 fragments of vessels were selected for petrographic studies. These fragments represent macroscopically diversified material both in shape and fabric and were excavated from the elongated pits of house no. 2 (Table S2). The analysis aimed to describe and recognise raw materials and technological features of the ceramic pastes, including admixtures, firing conditions and temperature. One sample (no. 10) came from the face vessel.

Thin sections from the ceramic sherds were analysed under a microscope with polarised light. Using point counting techniques, the relative abundances of certain compounds were established, including clay minerals, quartz, potassium feldspars, plagioclase, muscovite, biotite, carbonates, fragments of sedimentary, igneous and metamorphic rocks, fragments of reutilised ceramics (grog), as well as organic material (Table S3). The description of mineral composition also included silty grains and voids (pores, cavities). The percentage of these elements was established for every sample. The fabric description also included the degree of mixing of the ceramic fabric and the temperature and conditions of the firing process (Reedy, 2008, 109-210; Whitbread, 2017). An approximate temperature of the original firing was determined based on the thermal alteration of clay minerals, specifically the observation of the degree of transformation of a ceramic matrix into an amorphous, isotropic substance, and the observation of biotite minerals, hornblende, and glauconite (Bolewski, Żabiński, 1988; Quinn, 2013: 190-203; Daszkiewicz, Maritan, 2016). The division of grain fractions assumed in this paper followed the determinations formulated by the Soil Science Society of Poland (Polskie Towarzystwo Gleboznawcze, 2009).

2.2.2. Lipid residue analysis

A total of 34 sherds were selected for lipid residue analyses. The samples analysed included fragments from spherical vessels (*n* = 25), open bowls (*n* = 4), vessel with neck (*n* = 1) and pots from unknown typology (*n* = 2). Two samples associated with the face vessel were also sampled, namely a fragment of the face vessel and another sherd thought to be part of this pot (Table S4).

Lipid residue analyses and interpretations were based on established protocols (Evershed et al., 1990, Correa-Ascencio and Evershed, 2014). Briefly, analyses proceeded as follows: approximately 1 to 2 g ceramic fabric samples were taken, and their surfaces were cleaned using a modelling drill to remove any exogenous lipids (e.g., soil or finger lipids due to handling). The samples were then ground to a fine powder in a glass mortar using a pestle. The powdered sherd was transferred to a glass culture tube, an internal standard added for quantification (*n*-tetratriacontane, 20 μg) and an acidified methanol solution (H_2SO_4/MeOH, 4 % v/v, 5 mL, 70 °C, 1 h) was added. The lipids were then extracted from the aqueous phase with hexane (2 x 3 mL plus 2 x 2mL). The solvent was evaporated under a gentle stream of nitrogen to obtain the total lipid extract (TLE). Aliquots of the TLE (generally one quarter aliquots) were trimethylsilylated using *N,O*-bis (trimethylsilyl) trifluoroacetamide containing 1 % trimethylsilyl chloride (20 μL, 70 °C, 1 h) and re-dissolved into hexane for analysis by gas chromatography (GC-FID).

Combined GC-MS analyses were also performed on trimethylsilylated aliquots of the lipid extracts enabling the elucidation of structures of components not identifiable on the basis of GC retention time alone. The samples where animal fats were detected were submitted to GC-combustion-isotope ratio mass spectrometry (GC-C-IRMS) in order to distinguish between non-ruminant and ruminant fats, and dairy from adipose fats (Copley et al., 2003). The detection of potential aquatic biomarkers such as ω-(*o*-alkylphenyl) alkanoic acids and isoprenoid fatty acids were carried out using GC-MS analysis, following on from Cramp and Evershed (2014).

2.3. Lithic analysis

Raw materials used to make lithic artefacts were identified based on the author's experience and comparative collection stored in the ~~IAE PAS~~ Institute of Archaeology and Ethnology, Polish Academy of Sciences in Warsaw and Institute of Systematics and Evolution of Animals, Polish Academy of Sciences in Kraków. The lithic and obsidian artefacts were classified into four morphological groups following Lech (2012) and Werra et al. (2021). Among the lithic finds, 16 obsidian artefacts were detected during the archaeological excavations (Table S5), while 40 small items, mainly small chips, were found after wet-sieving of archaeobotanical samples (in the heavy fraction; mesh of 1 mm). Observations on flint assemblage were carried out on 861 items recorded during archaeological excavations.

2.3.1. XRF- analysis

All the 14 obsidian artifacts recovered from house no. 2 were analysed by using energy dispersive x-ray fluorescence (EDXRF) to determine their trace and selected minor element compositions. The derived chemical composition profiles were then compared with those of known obsidian sources to determine the most probable parent geological source for each artefact (i.e., artifact-to-"source", including geochemical type/variety attributions; Hughes, 1998)). EDXRF laboratory analysis conditions, instrumentation, geochemical type attribution procedures, element-specific measurement resolution, and literature references applicable to these samples follow those reported for artifacts from Rydno XIII/1959 (Hughes and Werra, 2014) and from other Mesolithic and Paleolithic sites in Poland (Hughes et al., 2018).

3. Results

3.1. Radiocarbon dating

The dating results indicated a chronology pointing toward the end of the sixth millennium BC (Fig. 5; Table 1). All the likelihoods, without any modelling, suggest a fairly long interval, i.e., spanning at least from about 5300 to 5000 BC (Fig. 6a). This does not imply that house no. 2 must have been in operation for 300 years. Instead, it suggests that it was in use for some period within those three centuries. After Bayesian modelling, considering the start and end dates of the 2sigma intervals for the start and end boundaries, respectively (Fig. 6a), the situation remains essentially unchanged. However, when considering the highest probability sections of these boundaries and the calibration curve in the relevant interval (Fig. 6b), the hypothetical timeframe for the functioning of house no. 2 shrinks to approximately 5200-5050 BC. Similarly, it cannot be argued that house no. 2 was occupied during the whole of that time.

3.2. Pottery analysis

More than 1100 pottery sherds were discovered in features connected with house no. 2. Their distribution was uneven, with a high concentration in the elongated pits on both sides of the house (features nos. 23 and 25). In contrast, in the south-western elongated pit (no. 24) and in one pit interpreted as a storage pit (no. 18), and post-holes, a smaller number of sherds were found. For 248 fragments, it was possible to reconstruct the form of the vessel. More than 75% of this assemblage is dominated by open bowls with varying degrees of walls eversion and spherical vessels. Vessels with a high neck appeared sporadically, while only one miniature vessel was found. The majority of the pot fragments are ornamented, especially with engraved lines, such as arched and paralleled (Fig. 7c and e). They are accompanied by notches, some of them quite long, crossing a few lines (Fig. 7g and d). Other motifs were recognised, including simple cuts, especially under the rim. The pots were frequently decorated with plastic elements, such as knobs and clay bands (Fig. 7f). Some of the sherds contain both kinds of ornament: engraved lines and plastic knobs (Fig. 7h), observed in fine and coarse ware. Also, finger and nail imprints occur as a part of decoration. Anthropomorphic, such as the face vessel (Fig. 7a), and zoomorphic motifs are very rarely found. The latter one is represented by a handle with a plastic decoration that resembles a head of an animal (Fig. 7b).

3.2.1. Petrography

Petrographic analyses of pottery fragments from house no. 2 have shown that the mineral composition of the ceramic masses includes components such as sandstone, mudstone and claystone (Table S2). The most common are silty clays (clay with an abundant quantity silty grains). Such clays are among the most available in the study area. Various admixture types were added to the clay, such as grog, sand and plant temper, perhaps depending on the pottery function.

To be more specific, six technological types are represented (Table S3, Fig. 8; Rauba-Bukowska et al. 2007; Rauba-Bukowska, 2014a; 20014b; Rauba-Bukowska, Czekaj-Zastawny, 2020). Most of the sherds were associated with technological types VI and VII, forming 59% of the assemblage (Fig. 8m-s) representing fine, medium and thick-walled pottery. The main components of ceramic fabric of type VI are clay minerals, silty grains and coarser grog fragments (Fig. 8m-o, grog shown with an arrow). The type VII (Fig. 8p-s) is similar to VI but, apart from grog, it contains sand admixture, while the main components of raw material are clay minerals, grains of quartz, feldspar, and fine mica flakes. Rare are heavy minerals and chalcedony. Technological type II is also common in this assemblage (19%) which represents a thin-walled pottery (fine ware; Fig. 8d-f). The main components of raw material are clay minerals, silty grains, and very fine mica flakes. Within fine-grained clay, microfossils of plankton appeared. Other technological groups were found infrequently in ceramic assemblages. The main components of the ceramic pastes of type I (Fig. 8a-c) are clay minerals, grains of silty fraction, fine mica flakes and iron oxides and hydroxides concentration. Pots made of paste type III (Fig. 8g-i) consist of clay minerals, poorly sorted quartz grains, feldspars and chalcedony grains. Rounded fragments of sedimentary (e.g., mudstone) or metamorphic (e.g., quartzites) rocks are present. The ceramic fabric of type IV (Fig. 8j-l) is characterized by lumpy structure and bigger porosity, caused by poorly mixed clay with fragments of sedimentary rocks, mostly claystone, mudstone and sandstone. The main admixture consists of plant fragments which, after destruction during firing, caused porosity. The face vessel represents type VII (Fig. 8p-s) and has ceramic fabric, which is medium to coarse grained with numerous sand grains and grog fragments. The raw material is silty clay with sand, composed mostly by quartz, feldspars and rarely quartzites.

3.2.2. Lipid residue analysis

A total of 17 sherds (50%) were dominated by $C_{16:0}$ (palmitic) and $C_{18:0}$ (stearic) fatty acids and interpreted as archaeological animal fats (Fig. 9). High concentrations of $C_{18:1}$ unsaturated fatty acids were present in six of these sherds likely indicating that these fats are not archaeological in origin (Whelton et al., 2021). The presence of cholesterol in some of these extracts also points towards modern contamination (Hammann et al.,2018). Those lipid extracts were not characterised further. Unfortunately, none of the sherds associated with the face vessel provided interpretable archaeological fats. Of the 11 sherds where archaeological animal fats were clearly identified, the main $C_{16:0}$ and $C_{18:0}$ fatty acids were accompanied by odd-carbon number fatty acids, biomarkers of bacterial populations from the rumen and characteristic from ruminant fats (Fig. 9a; Keeneyet al., 1962). Concentration of lipids in those sherds ranged between 6 µg and 4.16 mg per g of sherd (mean: 900 µg g^{-1}) (Table 3). The determination of animal fat types was achieved by measuring the $\delta^{13}C$ values of the main fatty acids ($C_{16:0}$ and $C_{18:0}$). The $\delta^{13}C_{16:0}$ values of lipid extracts ranged from -28.4 to -25.6‰ and were consistent with non-ruminant adipose fats (n = 4) and mixtures between non-ruminant and ruminant adipose fats (n = 7, Fig. 9b; Copley et al., 2003). The archaeological animal fats extracted from the coarse open bowls (n = 3) were all consistent with non-ruminant adipose fats; while spherical vessels displayed a wide range of animal fats, from non-ruminant adipose fats, to various mixtures of non-ruminant and ruminant adipose fats (Fig. 9c). No ω-(*o*-alkylphenyl) alkanoic acids were detected in the extracts; and 4,8,12-trimethyltridecanoic acid (TMTD) was detected in only one extract, suggesting very little evidence for the processing of aquatic resource in the pottery studied here (Table S). This can be in accordance with local landscape as the site is not located in close proximity to water reservoirs.

3.3. Lithic material

In archaeological features connected to house no. 2, a total of 877 lithic artefacts were detected during archaeological excavations. The majority of them (861 pieces) are made of flint, while the remaining ones are of obsidian (n = 16). Flint artifacts were mostly found in the fillings of two features (nos. 23 and 25; Fig. 10a). They mostly represent debitage and only 50 of them are implements (retouched tools and flint hammerstones). Concerning the flint assemblage, almost all specimens were made of mezo-local Jurassic-Cracow flint (95.3%), originating from outcrops located north and north-west of Kraków. Some flint items (1.7%)

were burned, and only two were made of so-called chocolate flint (0.2%), from either the north outskirts of the Holy Cross Mts. (ca. 170 km north-east of the site) or the central part of the Kraków-Częstochowa Upland (ca. 100 km north-west of the site; see Sudoł-Procyk et al. 2021).

A total of 15 items of flint artifacts belong to the first morphological group (natural nodules and cores) as defined by Lech (2012). These are primarily a blade cores with a single striking platform formed by single blow. Generally, cores have cortical sides, without traces of preparation and signs of faceting. The striking platform mostly is located on the narrow side of the core, but in a few cases on the wider side. The size of cores varies greatly, with length from 28 to 70 mm, width from 21 to 62 mm, and thickness from 23 to 48 mm. The cores are used up, often to residual forms or reused as hammerstones. The main purpose was to obtain blades, which were then the basis for the production of tools. The second group consists of 156 whole blade and their fragments, including 60 with a cortical surface. The third group (flakes and waste) is the most numerous – 603 items, including 148 cortical flakes and 141 chips. The fourth and last group, implements, includes 50 artifacts. Most of them are retouched blades and their fragments ($n = 23$), endscrapers ($n = 9$) and hammerstones ($n = 10$). Only four truncations, three retouched flakes and one perforator were registered.

Obsidian artifacts were found sporadically in six features, and the majority of them appeared in feature no. 23 (Fig. 10b). The short descriptions of each morphological group of obsidian artefacts appear in Table S5. The first group (natural nodules and cores) contains one item, a blade core, with a striking platform formed with the detachment of a single flake, showing signs of faceting, trace of preparation on the tip, but not on the sides (Fig. 11i). The second group consists of one whole blade and six blade fragments (Fig. 11a-d, g-h). The third group of eight artefacts comprises four flakes and four waste pieces (two of them were not geochemically analysed; Fig. 11e-f). Also, 40 items from archaeobotanical samples represent this group. No items were classified in the fourth and final group (implements).

3.3.1. Geochemical analysis of obsidian

The results of the quantitative geochemical analysis of large artifacts appear in Table S6, data for smaller specimens are listed in Table S7, and are illustrated graphically in Figure 12. The Sr/Zr data for eight specimens large enough for quantitative analysis (Table 6 and Fig. 11a, d-f, i) plot within the range established for Carpathian 1a/1b obsidians (Rosania et al., 2008) erupted in the Zemplén Mountains of southeast Slovakia (Fig. 12a). The other six obsidian specimens (Fig. 11:b, c, g, h) were too small and thin to generate x-ray counting statistics adequate for proper conversion from background-corrected intensities to quantitative concentration estimates (i.e., ppm), so they were analyzed to generate integrated net count (intensity) data for the elements Rb, Sr, Y, Zr, Nb, Fe and Mn (see Hughes, 2010 for analysis protocol). Background-subtracted intensities (counts per second) were converted to percentages, and source (geochemical type) assignments were made by comparing the plots for various element intensity ratios determined on artifacts against the parameters of known source types identified in Central Europe. Integrated net peak intensity data (Table S7, Fig. 12b) indicate that all six small flakes also were made from Carpathian 1a/1b obsidian.

4. Discussion

Chronology of the settlement at Biskupice

The nature of the ornamentation of the vessels from Biskupice indicates a classic, second stage of the Želiezovce phase of the LBK (Pavúk 1969; 1994; Kadrow 1990; 2020) with medium or long notches that intersect several thin and V-shaped lines. Several motif variants can be listed here. The most common are double, triple arc lines with intersecting notches, and multiple horizontal and diagonal straight lines. In addition, there are elements indicating a late sub-stage of the phase Želiezovce II, i.e., phase IIb (Pavúk 1969: Fig. 6; Kadrow 1990, 2020: 147; Dębiec, 2014: 226). They are characterized by very long notches, crossing even five or six lines of engraving. Only thin-walled spherical vessels and open bowls are decorated with engraved lines. In the area of south-western Slovakia, materials corresponding stylistically and chronologically to the Želiezovce IIb subphase occurred at many sites, such as Štúrovo (Pavuk, 1994), Bajč (Cheben, 2000), and Vráble (Furholt et al., 2020).

Among plastic decoration, there is a quite uncommon find of a handle that resembles a head of an animal (Fig. 7b). This kind of handles belongs to Type no. 2 (following Becker, 2007) and they are spatially and chronologically associated with the Želiezovce phase of the LBK (Becker, 2007: 23-24). Although some examples are known from western Germany, Austria and Czech Republic, there is a very distinct cluster of such pots in Moravia, south-western Slovakia, and north-western Hungary. The most similar analogies, due to the horizontal perforation in the handle, might be found in an assemblage of such handles from the settlement at the Danube valley in Mužla-Čenkov, okr. Nové Zámky (Kuzma, 1990: 441, figs. 13,31-32; 443, figs. 15,42). It is unclear what kind of animal is represented. Some scholars have indicated *bovidae* (after Becker, 2007:23), but in most cases, a convincing attribution is not possible.

To sum up, pottery from Biskupice correspond to the end of the LBK development in south-eastern Poland. **Data available in a few sites located near Kraków and Rzeszów (Czekaj-Zastawny, 2014: 103-105)** clearly indicate that the youngest LBK settlements fall on the Želiezovce IIb phase (Pavúk, 1969), after which this culture disappears and a hiatus is observed between the LBK and the next Neolithic unit (Czekaj-Zastawny, 2017). In Biskupice, the series of radiocarbon dates showed an existence of a plateau, although they indicated that the end of house no. 2 might have been situated around 5050/5000BC. In general, this corresponds to the radiocarbon dates acquired for the Želiezovce phase for Poland (Oberc et al., 2022).

Characteristic features of the pottery from Biskupice: local products versus *imported items*

Geological outcrops of Carpathian Flysch (Sub-Silesian Series) and Miocene sediments can be found in the neighbourhood of Biskupice (Burtan, 1954). The mineral and petrographic composition of the studied ceramic pastes are consistent with local geology, as components such as sandstone, mudstone and claystone come from Carpathian Flysch. Additionally, the presence of microfossils like plankton remnants points to local clay from marine Miocene sediments of the Carpathian Foredeep. Neolithic ceramic pastes containing microfossils or glauconite grains are known from a few sites near Kraków and Wieliczka, showing local sourcing of the raw material (e.g., Modlniczka site 5, Targowisko site 16; Rauba-Bukowska 2019; 2021). Pottery fragments that have been studied in detail show that the ceramic vessels from the site are made of local clays with an admixture of sand, grog and organic fragments. Furthermore, ceramic fabrics from Biskupice, as well as from other sites in Lesser Poland (Rauba-Bukowska, Czekaj-Zastawny, 2020) due to the addition of grog, show similarities to ceramic masses of the Bükk culture (Kozłowski et al., 2015; Czekaj-Zastawny et al., 2018).

The diagnostic features of the technology of pottery and the predominance of VI and VII technological types (59%) confirms late chronology of the Biskupice pottery assemblage (Želiezovce phase, see: Table 2) (i.a., Pavúk, 1969, fig. 6; Kozłowski et al. 2014; Kadrow and Rauba-Bukowska 2016; 2017; Czekaj-Zastawny et al., 2017; Moskal-del Hoyo et al., 2017; Kadrow, 2020, 147; Rauba-Bukowska, Czekaj-Zastawny, 2020). It was noticed that there was a significant change in the preparation of ceramic pastes in the LBK between the Music-Note (classical) and Želiezovce (late) phases (Rauba-Bukowska, Czekaj-Zastawny, 2020; Rauba-

Bukowska, 2021). It consists of several changes in the composition of the ceramic masses. First, a new type of admixture appeared, namely chamotte (grog; types VI and VII; Table S5), as fragments of sedimentary rocks were a component of ceramic masses in the olde and classical phases. Fabrics with an admixture of clay pellet were called type IV (Rauba-Bukowska et al., 2007; Rauba-Bukowska 2014, 2021; Rauba-Bukowska, Czekaj-Zastawny, 2021). These pastes were mainly used to make larger, coarse, thick-walled pots.The second significant change in the technology between ceramics of the Music-Note and the Želiezovce phase was the increasingly rare use of an organic admixture, consisting mostly of chaff fragments from domesticated cereals (Moskal del-Hoyo et al., 2017). This temper was very common in the older and classical phases of the LBK and was present in all types of ceramic fabrics, but more often was found in masses of type IV of thick-walled vessels. Plant fragments were also added to the clay in the Želiezovce phase, but without a clear correlation as to the type of ceramic mass.

Regarding firing conditions and temperatures, there have been almost no changes in this technological field during LBK period in Lesser Poland (e.g., Rauba-Bukowska et al. 2007; Rauba-Bukowska 2014; Kozłowski et al. 2014/2015; Rauba-Bukowska 2021). Firing usually took place in an atmosphere with a weak supply of air at temperatures around 650-800°C and rarely over 800°C. A similar structure of the method of firing is constant for the entire LBK and probably also for other Neolithic cultures, e.g., the Malice culture **(Rauba-Bukowska et al. 2007; Rauba-Bukowska 2021).** The collection of pottery from Biskupice studied here (n=27) does not differ from this scheme; firing prevails with a small supply of air at temperatures of 700-800°C.

The face vessel and the pottery with the zoomorphic handle (samples 10 and 25) show characteristic features of local ceramic paste, thus representing local production. This demonstrates that the idea of depicting anthropo- or zoomorphic representation was transferred from Transcarpathian areas rather than the vessels being imported. Similar cases were recently observed among LBK assemblages. For example, a study of an anthropomorphic figure from Kosina, showing a high similarity with the human figures from the Alföld Linear Pottery culture, was made of local clay (Dębiec et al., 2021).

Pottery use

Lipid residue analysis of pottery samples from Biskupice showed that animal fats were present, coming from ruminants and non-ruminants. Animal bones are not preserved at the site due to soil acidity, and thus lipid residue analyses provide a rare glimpse into animal management at the site. Ruminant fats are commonly found in LBK pottery, especially in northern area of its distribution such as the Kuyavia region, while non-ruminant adipose fats were rarely detected (Salque et al., 2013; Roffet-Salque et al., 2019). In one of the more comprehensive studies on lipid residues in the LBK pottery in Bylany (Czech Republic), ruminant adipose fats also predominated, whereas non-ruminant adipose fats were uncommon (Matlova et al., 2017; Brychova et al., 2020). The analysis of lipid residues from Biskupice did not demonstrate the presence of dairy products in the samples. No sieve pottery was found in this settlement, which is in line with southern and eastern Poland from where sieve pottery fragments appeared only at two archaeological sites at Gwoździec site 2 (Robson et al., 2021) and Puławy-Włostowice (Szeliga, 2018), but no finds are known from the Upper Vistula River settlement clusters. This gap in southern Poland is to be noted and can be observed on a map showing the distribution of sieve pottery in Central Europe (Saile et al., 2022, fig. 16).

Lipid residue analysis from Biskupice demonstrated that spherical vessels and open bowls of coarse ware were used to process animal carcass products. Although thin-walled pottery contained high concentrations of archaeological lipids, in Biskupice, the highest recovery rate was in coarse ware, which may suggest that vessels made of such fabric, were used especially for cooking. Similar observations were given in the case of a long-term LBK site 7 in Ludwinowo (Kuyavia, Poland), in which a comprehensive study of lipid residues analysis was conducted based on a large group of pottery sherds (n = 513). According to this study, coarse ware vessels were better adapted to cooking or it is possible that these kinds of pottery gave a high recovery rate and lipid concentration due to the fact that the lipids are preferentially absorbed in such a fabric compared to thin-walled vessels (Roffet-Salque et al., 2019).

Lithic industry: local raw material versus *imported*

The lithic industry was almost entirely based on local raw materials withJurassic-Cracow flint clearly dominating. This is not surprising, as Jurassic-Cracow flint prevails on LBK sites in southern Poland and was noted in 95% of all lithic assemblages. Obsidian, which is mostly represented by blanks and isolated cores, also occurred at almost all LBK sites in Lesser Poland. It is very exceptional in the early phase, sporadic in the middle phase and quite common in Phase III (Szeliga, 2009). In Biskupice, among raw materials other than Jurassic-Cracow flint obsidian prevailed, although it played a marginal role, accounting for less than 2%

of the lithic assemblage. Similar proportions were observed in the Upper Vistula River valley at Brzezie site 17 (Wilczyński, 2014) and other sites in Lesser Poland in Želiezovce phase (e.g., Kaczanowska et al., 1987; see also Szeliga, 2009), where only at two sites obsidian share exceeded 10% (Kraków-Nowa Huta Krzesławice site 41; Godłowska, 1982) and 19% (Gwoździec; Wilczyński and Kufel-Diakowska, 2021). On the other hand, in south-eastern areas of Poland, the share of obsidian was usually higher, around 10-20% (e.g., Rzeszów site 16; Kadrow, 1990; Zwięczyca site 3; Dębiec, 2014).

EDXRF data documented that all studied obsidian artefacts analysed from house no. 2 were manufactured from volcanic glass of the Carpathian 1a/1b chemical type, originating from southeast Slovakia on the borderland with northeast Hungary. Imports of obsidian in Lesser Poland seem to be related with areas of the Šariš Basin, Košice Basin, and East Slovak Lowland, where northern branches of the Tiszadob-Kapušany group and the Bükk culture developed, as confirmed by the imports of pottery (Kaczanowska and Godłowska, 2009; Czekaj-Zastawny, 2014, 2017). However, in Biskupice, the presence of cores, flakes and waste material, together with a group of tiny chips found in sediment samples (taken for archaeobotanical research), showed that it was raw material that was imported and then processed locally rather than the finished product. Geochemical analysis conducted on Neolithic obsidian artifacts from Poland also supports the dominance of the Carpathian 1a/1b obsidian variant (Kabaciński et al., 2015; Szeliga et al., 2019).

It is worth mentioning that in neighboring Czech Republic, Slovakia and Hungary, Carpathian1 obsidian also predominated at Neolithic sites, with only a minor representation of the Carpathian2 variant (Elburg et al., 2002; Biró, 2014; 2018; Constantinescu et al., 2014; Burgert et al., 2016; 2017; Riebe, 2019; Furholt et al., 2020; Werra et al., 2021). As Biró (2014: 64, fig. 13) has observed, obsidian of the Carpathian 1 chemical type seems to have been the most important volcanic glass used by prehistoric communities in East-Central Europe. The results from house no. 2 in Biskupice are consonant with this generalization.

Transcarpathian contacts

The analysis of pottery and lithic items from Biskupice essentially indicates the use of local materials. The majority of lithics were made from local flint, whereas obsidian artefacts were imported. Pots were produced from clays of local origin, although their technological and stylistic features are related with cultural influences from the areas located south of the Carpathians. Decorative motifs show patterns observed in the

Želiezovce group, while the usage of grog in clay masses is typical for the Bükk culture. However, among vessels found in house no. 2 there are no sherds with decoration known from the Bükk culture, which is quite surprising as this kind of pottery is often associated with obsidian finds. Such a situation is observed, for example, at Vráble, where obsidian finds, coming from the sources located in the eastern Slovak Carpathians, were found together with Bükk-style pottery sherds, based on the exchange with groups inhabiting the eastern Slovakia (Furholt et al., 2020).

Generally speaking, it should be emphasised that numerous fragments of vessels ornamented in the Eastern Linear styles have been found in Lesser Poland. They can be found in almost every LBK settlement excavated. Some of them were original forms that came from beyond the Carpathian Mountains. In some cases, however, analyses of the ceramic masses revealed the presence of imitations of imported vessels, i.e., locally produced vessels were decorated in the Eastern Linear styles (Czekaj-Zastawny, Rauba-Bukowska, 2014; Kadrow, Rauba-Bukowska, 2016; Czekaj-Zastawny et al., 2017; Dębiec et al., 2021), which isan excellent example of the exchange of ideas between the LBK and ALPC communities (Czekaj-Zastawny et al., 2017).

Based on pottery studies, it is possible to identify more precisely the areas from which imports flowed (Fig. 13). These include the Šariš Basin and the East Slovak Lowland, from where vessels characteristic of the Tiszadob-Kapušany group arrived almost from the beginning of the Music-Note phase of the LBK. In turn, in the Želiezovce phase, vessels of the Bükk culture were imported (Czekaj-Zastawny, 2014; Rauba-Bukowska, 2014). To date, a total of several dozen sites with Eastern Linear imports have been recorded in Poland (Kaczanowska, Godłowska, 2009; Czekaj-Zastawny, 2017, 52-55; Werra, Sobkowiak-Tabaka, 2017; Szeliga, Zakościelna, 2019). The intensification of contacts with the south is noticeable on LBK the territories in south-eastern Poland, especially from the end of the Music-Note phase (Godłowska 1976, 89-92; 1982; Kaczanowska, Godłowska, 2009; Kadrow, 1990).

The contacts with the Eastern Linear complex, although definitely weaker, reached much further than the Upper Vistula Basin - e.g., Upper Silesia. It is believed that some imports came here via the Lesser Poland groupings of the LBK. Ceramics from beyond the Carpathian Mountains took a similar route as far as the Polish Lowlands, including Kuyavia and Chełmno Land (Pyzel, 2009; Czekaj-Zastawny, 2017; Werra, Sobkowiak-Tabaka, 2017).

Analogous relationships can also be observed in other LBK areas, such as the area of the Szécsény Hills in the Nógrád Basin at the northern part of Cserhát Mountain and Ipoly Valley. There it was found that the Ipoly and Zagyva rivers served as important transport routes in the Early Neolithic. Ceramic and stone materials from Szécsény-Ültetés and several other investigated sites in the region indicate exchange with groups to the east, west and south, including Bükk, LBK, Vinča and Szakálhát (Fábián et al. 2016).

After the turn of the 6th and 5th millennia BC, with the disappearance of the LBK and Bükk culture, if viewed from a ceramic perspective, these contacts appear to have ceased as remains of imported southern vessels in the upper Vistula basin disappeared (Czekaj-Zastawny, 2017). However, if the non-ceramic perspective is taken into account, such contacts continued to function. Among other things, one observes an even more intensive influx of obsidian in the first half of the 5th millennium BC, visible above all in the early Lengyel-Polgár complex communities.

The presence of obsidian in Biskupice backs the thesis of the existence of long-distance connections between different "Linear" communities (Fig. 13; Lech, 1989; Wilczyński, 2016). The conveyance of artefacts made of obsidian could take various forms, from direct access, and mobility through trade, exchange, personal individual contact, among others. However, it is not possible to definitively determine how the exchange and contacts between Neolithic communities looked like, although some hypotheses were formulated and possible routes in the Western Carpathians were indicated (e.g., Valde-Nowak, 2009; Pelisiak, 2018). Due to the approximately 220 km distance from the deposit, direct contact with local groups cannot be ruled out. At the same time, the down-the-line exchange model cannot be excluded. It should be noted, of course, that this model likely included various combinations with other models proposed by Colin Renfrew (1975). Depending on the time and location, combinations could vary (see Kreig et al., 2023).

Obsidian in Biskupice, similarly to many other LBK sites, could probably be not only of economic importance (see Szeliga, 2021). "Foreign"/"exotic" items obtained from outside the family zone could have served a prestigious role, functioned as symbols, or as elements that indicated belonging to a specific community (Chapman, 2007).

5. Conclusions

A total of 10 samples, based on cereal grains and wild buckwheat fruits, from house no. 2 provided radiocarbon dating results. Their calibrated ranges show quite a long interval, pointing to dates between 5300 to 5000 BC. These results do not help in discerning a chronology of a use of this house and therefore do not shed light on the precise timeframe of the Želiezovce group in southern Poland. However, the existence of such decorative motifs as, for example, long notches crossing various lines, indicate that the Biskupice site can be one of the youngest settlements of this phase north of the Carpathian Mountains.

The petrographic analysis of the face vessel and a zoomorphic vessel from Biskupice have shown that they were produced locally. A study of the pottery assemblage from house no. 2 has not demonstrated the presence of any other vessel that could be treated as an import. This has been confirmed by a study of group of pottery sherds, which represented six technological types, as all of them have showed a use of local fabrics. Interestingly, the motifs of decoration are of Transcarpathian origins, suggesting that the ideas were transferred, mostly from the area of the Želiezovce group, but pottery items themselves were produced locally. On the other hand, among the lithic assemblage it has been demonstrated that obsidian was imported from sources extracted in the mountains located in present-day territory of south-eastern Slovakia. Although the share of obsidian artefacts is rather low, due to the presence of debitage, it can be concluded that the raw material was imported, and it was processed at the settlement. This observation confirms long-distance Transcarpathian connections between various groups of LBK communities.

Unfortunately, the face vessel has not given any evidence of lipid concentration, and therefore it is still difficult to speculate if it was actually used as container for storing or processing plant or animal remains. The analysis of lipid residues of selected groups of pottery sherds has demonstrated that animal fats from ruminant and non-ruminant were used for cooking at the settlement. Also, a use of aquatic animals has been confirmed. This is especially important as animal bones have not been preserved due to soil conditions, and it gives additional information about food processing and animal husbandry.

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References:

Becker, V., 2007. Rinder, Schweine, Mischwesen: Zoomorphe Funde der westlichen Linearbandkeramik. Habelt, Bonn.
Biró, K.T., 2014. Carpathian Obsidians: State of Art. In: Yamada, M., Ono, A. (Eds.), Lithic Raw Material Exploitation and Circulation in Prehistory. A Comparative Perspective in Diverse Palaeoenvironments. ERAUL 138, Liège, pp. 47–69.
Bolewski, A., Żabiński, W. (Eds.), 1988. Metody badań minerałów i skał. Wydawnictwo Geologiczne, Warszawa.
Bronk Ramsey, C., 2009. Bayesian analysis of radiocarbon dates. Radiocarbon 51 (1), 337–360.
Brock, F., Higham, T., Ditchfield, P., Bronk Ramsey, C., 2010. Current Pretreatment Methods for AMS Radiocarbon Dating at the Oxford Radiocarbon Accelerator Unit (Orau). Radiocarbon, 52, 102-112.
Brychova V., Roffet-Salque, M., Pavlu, I., Kyselka, J., Sedlarova, I., Filip, V., Evershed, R.P., 2020. Defining pottery use and animal management at the Neolithic site of Bylany (Czech Republic). Journal of Archaeological Science: Reports 14, 262-274.
Burgert, P., Přichystal, A., Prokes, L., Petřík, J., Hušková,S., 2016. Původ obsidiánové suroviny v pravěku Čech. Archeologicke Rozhledy 68, 224–234.
Burgert, P., Přichystal, A., Prokes, L., Petřík, J., Hušková, S., 2017. The origin and distribution of obsidian in prehistoric Bohemia. Bulgarian e-Journal of Archaeology 7, 1–15.
Burtan, J., 1954. Szczegółowa mapa geologiczna Polski w skali 1:50000. Arkusz Wieliczka (M34-77A). Instytut Geologiczny, Warszawa.
Chapman J. 2007. Engaging with the exotic: the production of early farming communities in South-East and Central Europe. In M. Spataro and P. Biagi (eds), A short walk through the Balkans. The first farmers of the Carpathian Basin and adjacent regions. Quaderno 12. Trieste: Società per la preistoria i protostoria della regione Friuli-Venezia Giulia, 207-222.
Cheben, I., 2000. Bajč – eine Siedlung der Želiezovce-Gruppe: Entwicklungsende der Želiezovce-Gruppe und Anfänge der Lengyel-Kultur. Universitätsforschungen zur prähistorischen Archäologie, Band 68. Aus dem Seminar für Vor- und Frühgeschichte der Universität Frankfurt. M. Verlag Dr. Rudolf Habelt GmbH, Bonn.
Copley, M.S., Berstan, R., Dudd, S. N., Docherty, G., Mukherjee, A. J., Straker, V., Payne, S. and Evershed, R.P., 2003. Direct chemical evidence for widespread dairying in prehistoric Britain." Proceedings of the National Academy of Sciences of the United States of America 100(4), 1524-1529.
Correa-Ascencio, M., Evershed, R.P., 2014. High throughput screening of organic residues in archaeological potsherds using direct methanolic acid extraction. Analytical methods 6, 1330-1340.
Cramp, L.J.E., Evershed, R.P., 2014. Reconstructing aquatic resource exploitation in human Prehistory using lipid biomarkers and stable isotopes. Treatise on geochemistry: archaeology and anthropology. In: Holland, H.D., Turekian, K.K., (Eds.). Elsevier, Oxford, 319-339.

Constantinescu, B., Cristea-Stan, D., Kovács, I., Szőkefalvi-Nagy, Z., 2014. Provenance studies of Central European Neolithic obsidians using external beam milli-PIXE spectroscopy. Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms 318, 145–148.

Czekaj-Zastawny, A., 2009. Settlement of the Linear Pottery Culture in Southeastern Poland (The First Neolithic Sites in Central/South-East European Transect Volume V = BAR S2049), Oxford.

Czekaj-Zastawny, A., 2014. Brzezie 17. Osada kultury ceramiki wstęgowej rytej. (Via Archaeologica. Źródła z badań wyko- paliskowych na trasie autostrady A4 w Małopolsce). Krakowski Zespół do Badań Autostrad, Kraków.

Czekaj-Zastawny, A., 2017. The first farmers from the South – Linear Pottery culture. In: Włodarczak,P. (Ed.), 5500 – 2000 BC (= The Past Societies. Polish lands from the first evidence of human presence to the Early Middle Ages, vol. 2, P. Urbańczyk Ed.). IAE PAN, Warszawa, pp. 21-62.

Czekaj-Zastawny A., Rauba-Bukowska A. 2014. Technology of the earliest vessels in the upper Vistula River basin — imports against local pottery, [in:] T.L. Kienlin, P. Valde-Nowak, M. Korczyńska, K. Cappenberg, J. Ociepka (eds.), Settlement, Communication and Exchange around the Western Carpathians. International Workshop held at the Institute of Archaeology, Jagiellonian University, Kraków, October 27–28, 2012, Oxford, p. 95–107;

Czekaj-Zastawny A., Kadrow, S., Rauba-Bukowska, A. 2017. Ceramic raw material acquisition and transfer of technological ideas among the Early Neolithic communities around the Western Carpathians. In: Burnez-Lanotte, L. (Ed.), Matières à Penser: Raw materials acquisition and processing in Early Neolithic pottery productions. Matières à penser: sélection et traitement des matières premières dans les productions potières du Néolithique ancien. Proceedings of the Workshop of Namur (Belgium) Actes de la table ronde de Namur (Belgique) 29 et 30 mai 2015 – 29 and 30 May 2015 (= Société. Préhistorique Française 11). Société Préhistorique Française, Paris, pp. 81-91.

Czekaj-Zastawny A., Rauba-Bukowska A., Hreha R., 2018. Colorants used for decoration of the Bükk Culture vessels. In: Valde-Nowak, P., Sobczyk, K., Nowak, M., Źrałka, J. (Eds.), Multas per gentes et multa per saecula. Amici magistro et collegae suo Ioanni Christopho Kozłowski dedicant. Kraków: Jagiellonian University in Kraków, Alter, 351-359.

Czekaj-Zastawny, A., Rauba-Bukowska, A., Kukułka, A., Kufel-Diakowska, B, Lityńska-Zając, M., Moskal-del Hoyo, M., Wilczyński, J., 2020 The earliest farming communities north of the Carpathians: The settlement at Gwoździec site 2. PLoS ONE, 15(1), e0227008.

Czekaj-Zastawny, A., Rauba-Bukowska, A., Kukułka, A., Bochnia, M., 2021. Ceramika naczyniowa kultury ceramiki wstęgowej rytej. In: Czekaj-Zastawny, A., Rauba-Bukowska, A., Kukułka, A. (Eds.), Najstarsza osada kultury ceramiki wstęgowej rytej z terenu Polski Gwoździec stan. 2, gm. Zakliczyn/The earliest settlement of the Linear Pottery Culture from the territory of Poland Gwoździec site 2, com. Zakliczyn. Instytut Archeologii i Etnologii PAN, Muzeum Okręgowe w Tarnowie, Kraków, 63-123.

Daszkiewicz, M., Maritan, L., 2016. Experimental Firing and Re-firing. In: Hunt, A.M.W. (Ed.), The Oxford Handbook of Archaeological ceramic Analysis. Oxford: Oxford University Press, 487-508, Pl. 5-9.

Dębiec, M., 2014. Zwięczyca 3. Eine Bandkeramische Siedlung Am Wisłok. Oficyna Wydawnicza ZIMOWIT, Rzeszów.

Dębiec, M., Saile, T., Alagierski, P., Rauba-Bukowska, A., 2021. Ein Ungar In Polen. Zu Einer Frühneolithischen Statuette Aus Kosina 62 Bei Łańcut Im Südöstlichen Polen. Archäologisches Korrespondenzblatt 51, 23-35.

Elburg, M., Elburg, R., Greig, A., 2002. Obsidian in Sachsen und die Verwendung von ICP-MS zur Herkunftsbestimmung von Rohmaterialien. Arbeits- und Forschungsberichte zur sächsischen Bodendenkmalpflege 44, 391–397.

Evershed, R. P., Heron, C., Goad, L.J., 1990. Analysis of organic residues of archaeological origin by high-temperature gas chromatography and gas chromatography-mass spectrometry. The Analyst 115: 1339-1342.

Fábián, S. 2010. Siedlung Der Zseliz-Periode Der Linearbandkeramik in Szécsény-Ültetés. Antaeus 31–32 (2010) 225–283.

Furholt, M., Cheben, I., Müller, J., Bistáková, A., Wunderlich, M., Müller-Scheessel, N. (Eds.) 2020. Archaeology In The Žitava Valley I. The LBK and Želiezovce settlement site of Vráble (=Scales of Transformation in Prehistoric and Archaic Societies 9). Sidestone Press, Leiden.

Furholt, M., Müller-Scheeßel, N., Wunderlich, M., Cheben, I., Müller, J., 2020. Communality and Discord in an Early Neolithic Settlement Agglomeration: The LBK Site of Vráble, Southwest Slovakia. Cambridge Archaeological Journal 30, 469-489.

Godłowska, M., 1982. Nowohucki zespół osadniczy na tle wpływów południowych we wczesnym i środkowym neolicie Małopolski. Wiadomości Archeologiczne 47, 143-160.

Golański, S. Rzepecki and M. Wąs (eds), Nie tylko krzemienie. Not only flints. Studia ofiarowane prof. Lucynie Domańskiej w 45-lecie pracy naukowo-dydaktycznej i w 70. rocznicę urodzin. Łódź: Instytut Archeologii Uniwersytetu Łódzkiego; Łódzka Fundacja Badań Naukowych; Stowarzyszenie Naukowe Archeologów Polskich Oddział w Łodzi, 237-247.

Wilczyński J. 2018. Chipped stone inventories of the malice culture from southern Poland, In: Valde-Nowak, P., Sobczyk, K., Nowak, M., Źrałka, J. (eds), "Multas per gentes et multa per saecula", Kraków, pp. 451-458.

Govindaraju, K., 1994. Compilation of working values and sample description for 383 geostandards. Geostandards Newsletter, Special Issue XVIII, 1-158.

Hammann, S., Cramp, L. J. E., Whittle, M., Evershed, R.P. 2018. Cholesterol degradation in archaeological pottery mediated by fired clay and fatty acid pro-oxidants. Tetrahedron Letters 59(50), 4401-4404.

Hughes, R.E., 1998. On reliability, validity, and scale in obsidian sourcing research. In: Ramenofsky, A.F., Steffen, A. (Eds.), Unit Issues in Archaeology: Measuring Time, Space, and Material. University of Utah Press, Salt Lake City, pp. 103–114.

Hughes, R.E., 2010. Determining the geologic provenance of tiny obsidian flakes in archaeology using nondestructive EDXRF. American Laboratory 42 (7), 27-31.

Hughes, R.E., Werra, D.H., 2014. The source of Late Mesolithic obsidian recovered from Rydno XIII/1959, Central Poland. Archeologia Polski 59(1-2), 31–46.
Hughes, R.E., Werra, D.H., Sulgostowska, Z. 2018. On the Sources and Uses of Obsidian During the Paleolithic and Mesolithic in Poland. Quaternary International 468, 84-100.
Kabaciński, J., Sobkowiak-Tabaka, I., Kasztovszky, Z., Pietrzak, S., Langer, J.J., Biró, K.T., Maróti, B. 2015. Transcarpathian influences in the Early Neolithic of Poland. A case study of Kowalewko and Rudna Wielka sites. Acta Archaeologica Carpathica 50, 5–32.
Kaczanowska, M., Godłowska, M. 2009. Contacts between the Eastern and Western Linear Cultures in South-Eastern Poland.In: Kozłowski, J.K. (Ed.), Interactions between different models of Neolithization North of the Central European Agro-Ecological Barrier.Polska Akademia Umiejętności,Kraków, pp. 137-150.
Kaczanowska, M., Kozłowski, J.K., Zakościelna, A., 1987.Chipped Stone Industries of the Linear Band Pottery Culture Setllements in the Nowa Huta Region. Przegląd Archeologiczny 34, 93-132.
Kadrow, S., 1990. Osada neolityczna na stan. nr 16 w Rzeszowie na Osiedlu Piastów. Sprawozdania Archeologiczne 41, 9-76.
Kadrow, S., 2020. Faza i styl żeliezowski kultury ceramiki wstęgowej rytej w Polsce południowowschodniej. In: Dębiec, M., Saile, T. (Eds.), A planitiebus usque ad montes. Studia archaeologica Andreae Pelisiak vitae anno sexagesimo. Rzeszów, pp. 143-152.
Kadrow, S., Rauba-Bukowska, A., 2016. Ceramics Technology and Transfer of Ideas in the West Carpathian Region in Neolithic. In: Ţerna, S., Govedarica, B. (Eds.), Interactions, Changes and Meanings. Essays in honour of Igor Manzura on the occasion of his 60th birthday. University of High Anthropological School, Kishinev, pp. 65-72.
Kadrow, S., Rauba-Bukowska, A., 2017. The selection of ceramic raw material: convenience or a technologicalidea? A case study of the Danubian cultures north of the Carpathians. Archeologické rozhledy 69, 261-280.
Kaminská L'. 2018. Use of obsidian from the Paleolithic to the Bronze Age in Slovakia. Archeometriai Műhely 15(3), 197-212.
Kapcia M., Moskal-del Hoyo M., Korczyńska-Cappenberg M., Wacnik A., Kenig R., Nowak M. 2023. Early Neolithic plant remains from the Carpathian foothill zone (southern Poland): a case study of the Biskupice site no. 18. In: Engelbogen, F., Taylor, N., Ricci A. (Ed.), Abstract Book Kiel Conference. Scales of Social, Environmental & Cultural Change in Past Societies. Kiel University, March 13–18, 2023. Abstract book: 58. doi.org/10.38071/2023-00120-3
Keeney, M., Katz, I. and Allison, M.J., 1962. On the probable origin of some milk fat acids in rumen microbial lipids. Journal of the American Oil Chemists' Society 39(4), 198-201.
Kerig, T., Hilpert, J., Strohm, S., Berger, D., Denis, S., Gauthier, E., Gibaja, J.F., Mallet N., Massa M., Mazzucco N., Nessel B., Pelegrin J., Pétrequin P., Sabatini S., Schumacher T.X., Serbe B.and Wilkinson, T. (2023). Interlinking research: The Big Exchange project. Antiquity, 97(394), E22. doi:10.15184/aqy.2023.78
Kondracki, J., 1998. Geografia regionalna Polski. Polskie Wydawnictwo Naukowe, Warszawa.
Korczyńska, M., Kenig, R., Nowak, M., Czekaj-Zastawny, A., Nowak, M., Moskal-del Hoyo, M., 2021 Linear Pottery culture face vessel from the site Biskupice 18, southern Poland. Sprawozdania Archeologiczne 73/1, 155-186.

Kozłowski J.K. 1968. Materiały neolityczne i eneolityczne odkryte na stanowisku Nowa Huta-Wyciąże I (badania w latach 1950-1952). Materiały Archeologiczne Nowej Huty 1, 13-90.
Kozłowski J.K. 2006. Grupa Wyciąże-Złotniki i bezpośrednie oddziaływania polgarskie. In: Kaczanowska, M. (Ed.), Dziedzictwo cywilizacji naddunajskich: Małopolska na przełomie epoki kamienia i miedzi. Kraków: Muzeum Archeologiczne w Krakowie, 53-61.
Kozłowski, J.K., Kaczanowska, M., Czekaj-Zastawny, A., Rauba-Bukowska, A., Bukowski, K., 2014. Early/Middle Neolithic Western (LBK) vs Eastern (ALPC) Linear Pottery Cultures: Ceramics and Lithic Raw Materials Circulation. Acta Archaeologica Carpathica 49, 37-76.
Kuzm, I., 1990. Plastika Želiezovskej skupiny z Mužle-Čenkova. Slovenská Arch. 38/2, 429-452.
Lech, J., 1989. A Danubian raw material exchange network: a case study from Bylany. In: Rulf, J. (Ed.), Bylany Seminar 1987: Collected papers. Praha: Archeologický ústav CSAV, 111-120.
Lech, J., 2012. The late Neolithic flint and stone industries. In: Longworth, I., Varndell, G., Lech, J. (Eds.), Excavations at Grimes Graves Norfolk 1972–1976. Fascicule 6. Excavation and Exploration beyond the Deep Mines. British Museum Press for the Trustees of the British Museum, London, pp. 90–144.
Matlova, V., Roffet-Salque, M., Pavlu, I., Kyselka, J., Sedlarova, I., Filip, V., Evershed, R.P., 2017. Defining pottery use and animal management at the Neolithic site of Bylany (Czech Republic). Journal of Archaeological Science: Reports 14, 262-274.
Moskal-del Hoyo, M., Korczyńska-Cappenberg M., Kenig R., 2022 (unpublished). Raport z weryfikacyjnej prospekcji powierzchniowej, przeprowadzonej w Biskupicach na obszarze AZP 104-58, unpublished manuscript. Wojewódzki Urząd Ochrony Zabytków w Krakowie.
Moskal-del Hoyo, M., Rauba-Bukowska, A., Lityńska-Zając, M., Mueller- Bieniek, A., Czekaj-Zastawny, A., 2017. Plant materials used as temper in the oldest Neolithic pottery from south-eastern Poland. Vegetation History and Archaeobotany 26, 329-344.
Nowak, M., Moskal-del Hoyo, M., Mueller-Bieniek, A., Lityńska- Zając, M., Kotynia, K., 2017. Benefits and weaknesses of radiocarbon dating of plant material as reflected by Neolithic archaeological sites from Poland, Slovakia and Hungary. Geochronometria 44, 188–201.
Oberc, T., Czekaj-Zastawny, A., Rauba-Bukowska, A., 2022. Radiocarbon dating for the Linear Pottery Culture from the territory of Poland – research problems. In: Grygiel, M., Obst, P. (Eds.), Walking Among Ancient Trees. Studies in honour of Ryszard Grygiel and Peter Bogucki on the 45th anniversary of their research collaboration. Fundacja Badań Archeologicznych Imienia Profesora Konrada Jażdżewskiego. Muzeum Archeologiczne i Etnograficzne w Łodzi, Łódź, pp. 184-212.
Pavúk, J., 1969. Chronologie der Želiezovce-Gruppe. Slovenská Archeológia 17, 269-367.
Pavúk, J., 1994. Štúrovo. Ein Siedlungsplatz der Kultur mit Linerakeramik und der Želiezovce-Gruppe. Nitra.
Pelisiak, 2018. Centrum i peryferia osadnictwa w neolicie i wczesnej epoce brązu na wschodnim Podkarpaciu i we wschodniej części polskich Karpat [Core and Peripheries of the Neolithic and Early Bronze Age Settlements on the Eastern Carpathian Forelands and the Eastern Part of Polish Carpathians]. Wydawnictwo Uniwersytetu Rzeszowskiego. Rzeszów.

Polskie Towarzystwo Gleboznawcze, 2009. Klasyfikacja uziarnienia gleb i utworów mineralnych PTG 2008. Roczniki Gleboznawcze 60/2, 5-16.

Pyzel J. 2009. Migration und Kontakte in der Bandkeramik Kujawiens. In: Krenn-Leeb, A., Beier, H.-J., Claßen, E., Falkensten, F., Schwenzer, S. (Eds), Varia Neolithica 5. Mobilität, Migration und Kommunikation in Europa während des Neolithikums und der Bronzezeit. Beiträge der Sitzungen der Arbeitsgemeinschaften Neolithikum und Bronzeit während der Jahrestagung des West- und Süddeutschen Verbandes für Altertumsforschung e. V. in Xanten, 6.-8- Juni 2006 (= Beiträge zur Ur- und Frühgeschichte Mitteleuropas 53). Langenweißbach: Beier & Beran Archäologische Fachliteratur, 49-52.

Quinn, P.S., 2013. Ceramic Petrography. The Interpretation of Archaeological Pottery and Related Artefacts in Thin Section. Archaeopress, Oxford.

Rauba-Bukowska A. 2014a. Wyniki badań mineralogiczno-petrograficznych naczyń kultury ceramiki wstęgowej rytej ze stanowiska Brzezie 17 gm. Kłaj. In: Czekaj-Zastawny, A., Brzezie 17. Osada kultury ceramiki wstęgowej rytej (= Via Archaeologica. Źródła z badań wykopaliskowych na trasie autostrady A4 w Małopolsce). Kraków: Krakowski Zespół do Badań Autostrad,437-458.

Rauba-Bukowska A. 2014b. Wyniki badań mineralogiczno-petrograficznych naczyń importowanych kręgu wschodniolinearnego, odkrytych na stanowisku Brzezie 17, gm. Kłaj. In: Czekaj-Zastawny, A., Brzezie 17. Osada kultury ceramiki wstęgowej rytej (= Via Archaeologica. Źródła z badań wykopaliskowych na trasie autostrady A4 w Małopolsce). Kraków: Krakowski Zespół do Badań Autostrad, 459-468.

Rauba-Bukowska, A., 2019. The diversity of ceramic raw materials used in the production of Neolithic vessels in the upper Vistula basin near Krakow. Analecta Archaeologica Ressoviensia 14, 11-20.

Rauba-Bukowska, A., 2021.Technological indicators in the pottery production of the late Linear Pottery culture and the Malice culture. Sprawozdania Archeologiczne 73-1, 119-151.

Rauba-Bukowska, A, Czekaj-Zastawny, A., 2020. Changes in the pottery production of the Linear Pottery Culture – origins and directions of ideas. In: Spataro,M., Furholt, M. (Eds.), Detecting and explaining technological innovation in prehistory (= Scales of Transformation 7). Sidestone Press, Leiden, pp. 73-83.

Rauba-Bukowska, A., Czekaj-Zastawny, A., Grabowska, B., Zastawny, A., 2007. Wyniki badań mineralogiczno-petrograficznych naczyń kultury ceramiki wstęgowej rytej i malickiej ze stanowisk Brzezie 17 i Targowisko 11, gm. Kłaj, woj. Małopolskie, Results of mineralogical and petrographic research on vessels of linear band pottery culture and malice culture from sites Brzezie 17 and Targowisko 11, Kłaj commune, małopolska province. Sprawozdania Archeologiczne 59, 63-113.

Reedy, Ch.L., 2008. Thin-Section Petrography of Stone and Ceramic Materials. London: Archetype Publications.

Reimer, P.J., Bard, E., Bayliss, A., Beck, J.W., Blackwell, P.G., Ramsey, C.B., Buck, C.E., Cheng, H., Edwards, R.L., Friedrich, M., Grootes, P.M., Guilderson, T.P., Haflidason, H., Hajdas, I., Hatté, C., Heaton, T.J., Hoffmann, D.L., Hogg, A.G., Hughen, K.A., Kaiser, K.F., Kromer, B., Manning, S.W., Niu, M., Reimer, R.W., Richards, D.A., Scott, E.M., Southon,

J.R., Staff, R.A., Turney, C.S.M., van der Plicht, J., 2013. IntCal13 and Marine13 radiocarbon age calibration curves 0–50,000 years cal BP. Radiocarbon 55, 1869–1887.
Renfrew, C. M. (1975). Trade as action at a distance, questions of integration and communication. In Sabloff, J. A., and Lamberg-Karlovsky, C. C. (eds.), Ancient Civilization and Trade, University of New Mexico Press, Albuquerque, pp. 3–59.
Riebe, D.J., 2019. Sourcing Obsidian from Late Neolithic Sites on the Great Hungarian Plain: Preliminary p-XRF Compositional Results and the Socio-Cultural Implications. Interdisciplinaria Archaeologica 10, 113–120.
Roffet-Salque, M., Banecki, B., Krüger, M., Pyzel, J., Smyth, J., Evershed, R.P., 2019. Chronologiczne i przestrzenne trendy użytkowania ceramiki w świetle analiz pozostałości tłuszczów w naczyniach KCWR / Chronological and spatial trends in pottery use revealed through lipid residue analyses of LBK pottery vessels.In: Pyzel, J. (Ed.), Ludwinowo, stanowisko 7. Osada neolityczna na Kujawach. Wydawnictwo i pracownia archeologiczna Profil-Archeo/Wydawnictwo Uniwersytetu Gdańskiego, Pękowice-Gdańsk, pp. 301-316.
Robson, H.K., England, F., Lucquin, A., Craig, O.E., 2021. Analiza pozostałości organicznych w ceramice (ORA – Organic Resiude Analysis). In: Czekaj-Zastawny, A., Rauba-Bukowska, A., Kukułka, A. (Eds.), Najstarsza osada kultury ceramiki wstęgowej rytej z terenu Polski Gwoździec stan. 2, gm. Zakliczyn/The earliest settlement of the Linear Pottery Culture from the territory of Poland Gwoździec site 2, com. Zakliczyn. Instytut Archeologii i Etnologii PAN, Muzeum Okręgowe w Tarnowie, Kraków, pp. 132-141.
Rosania, C.N., Biró K.T., Ryzhov S., Trnka, G., Glascock, M.D., 2008. Revisiting Carpathian Obsidian. Antiquity Project Gallery 82.
Saile, T., Dębiec, M., Buzea, D., 2022. Aspects of a Bandkeramik settlement near Olteni in Transylvania. Praehistorische Zeitschrift 97(1), 1–21.
Salque, M., Grygiel, R., Szmyt, M., 2013. Earliest evidence for cheese making in the sixth millennium BC in northern Euro-pe. Nature 493, 522–525.
Sudoł-Procyk, M., Brandl, M., Krajcarz, M., Malak, M., Skrzatek, M., Stefański, D., Trela-Kieferling, E., Werra, D. H. 2021. Chocolate flint: New perspectives on its deposits, mining, use and distribution by prehistoric communities in Central Europe. Antiquity 95(383), e25.
Szeliga, M., 2009. Znaczenie obsydianu karpackiego w gospodarce surowcowej najstarszych społeczności rolniczych na ziemiach polskich. In: Gancarski, J. (Ed.), Surowce Naturalne w Karpatach Oraz Ich Wykorzystanie w Pradziejach i Wczesnym Średniowieczu. Krosno, pp. 287–324.
Szeliga, M., 2018. Osadnictwo kultury ceramiki wstęgowej rytej. In: Niezabitowska-Wiśniewska, B., (Ed.), Puławy-Włostowice. Wielokulturowe stanowisko z zachodniej Lubelszczyzny / Puławy-Włostowice. Multicultural site in the western Lublin region. Instytut Archeologii Marii Curie-Skłodowskiej w Lublinie, Lublin, pp. 176-221.
Szeliga M. 2021. The inflow of obsidian north of the Carpathians during the Neolithic - chrono-cultural variability of distribution. In: Biró, K.T., Markó, A. (Eds), Beyond the Glass Mountains. Papers Presented for the 2019 International Obsidian Conference 27-29 May 2019, Sárospatak (= Inventaria Praehistorica Hungariae 14). Budapest: Magyar Nemzeti Múzeum, 69-94.

Szeliga, M., Kasztovszky, Z., Szilágyi, V., 2019. New PGAA data on the origin of Early Neolithic (LPC) obsidian in the upper Vistula Basin. In: Markó, A., Szilágyi, K., Biró, K.T. (Eds.), International Obsidian Conference 2019 27–29 May 2019, Sárospatak (Hungary), Program, Abstracts, Field Guide. Hungarian National Museum, Budapest, pp.63.
Valde-Nowak, P., 2014. Long Houses on Hilltop – Camps in the Mountains: Some Aspects of the Neolithic in the Dunajec Project. In: Kienlin, T.L., Valde-Nowak, P., Korczyńska, M., Cappenberg, K., Ociepka, J. (Eds.), Settlement, Communication and Exchange around the Western Carpathians.International Workshop at the Institute of Archaeology, Jagiellonian University in Kraków October 27–28, 2012. Archaeopress Archaeology, Oxford, pp. 27-49.
Valde-Nowak, P., 2009. Early farming adaptation in the Wiśnicz Foothills in the Carpathians. Settlements at Łoniowa and Żerków. Recherches Archéologiques 1: 15–35.
Werra, D.H., Hughes, R.E., Nowak, M., Vizdal, M., Gačková, L., 2021. Obsidian Source Use within the Alföld Linear Pottery culture in Slovakia. Sprawozdania Archeologiczne, 73(1), 331–369.
Werra, D.H., Sobkowiak-Tabaka, I. 2017. Elementy kultury bukowogórskiej na Nizinie Polskiej – aspekt teoretyczny. In A. Marciniak-Kajzer, A. Andrzejewski, Aleksander, A., Golański, A., Rzepecki, S., Wąs, M. (Eds), Nie tylko krzemienie/Not only flints. Studia ofiarowane prof. Lucynie Domańskiej w 45-lecie pracy naukowo-dydaktycznej i w 70. Rocznicę urodzin. Łódź, pp. 237–247.
Whelton, H.L., Hammann, S., Cramp, L.J.E., Dunne, J., Roffet-Salque, M., Evershed, R.P., 2021. A call for caution in the analysis of lipids and other small biomolecules from archaeological contexts. Journal of Archaeological Science 132, 105397.
Whitbread, I.K., 2017.Fabric Description of Archaeological Ceramics. In: Hunt, A.M.W. (Ed.), The Oxford Handbook of Archaeological Ceramic Analysis. Oxford University Press, Oxford, pp. 200-216.
Wilczyński, J., 2014. Neolityczny inwentarz krzemienny oraz obsydianowy z wielokulturowego stanowiska Brzezie 17. In: Czekaj-Zastawny, A., (Ed.), Brzezie 17. Osada kultury ceramiki wstęgowej rytej (Via Archaeologica. Źródła z badań wykopaliskowych na trasie autostrady A4 w Małopolsce). Krakowski Zespół do Badań Autostrad, Kraków, pp. 499-546.
Wilczyński, J., 2016. Flint, Obsidian, and Radiolarite in Lithic Inventories of the LBK culture in Lesser Poland. In: Amkreutz, L., Haack, F., Hofmann, D., van Wijk, I. (Eds.), Something out of the Ordinary?: Interpreting Diversity in the Early Neolithic Linearbandkeramik and Beyond. Newcastle upon Tyne: Cambridge Scholars Publishing, 123-139.
Wilczyński, J., Kufel-Diakowska, B., 2021. Wyroby kamienne. In: Czekaj-Zastawny, A., Rauba-Bukowska, A., Kukułka, A. (Eds.), Najstarsza osada kultury ceramiki wstęgowej rytej z terenu Polski. Gwoździec stan. 2, gm. Zakliczyn [The earliest settlement of the Linear Pottery Culture from the territory of Poland. Gwoździec site 2, com. Zakliczyn], Kraków: IAE PAN, Muzeum Okręgowe w Tarnowie, pp. 142-215.

Captions:

Fig. 1. Location of the site 18 in Biskupice against the background of the LBK settlement in western Lesser Poland (Czekaj-Zastawny 2014, fig. 57).

Fig. 2. Plan of the archaeological excavations at Biskupice site 18. Remnants of at least four houses were discovered (black rectangles). Photo: M. Korczyńska-Cappenberg.

Fig. 3. Location of pit no. 25 within house no. 2 at Biskupice site 18, in which the face vessel was found. Photos: M. Korczyńska-Cappenberg and A. Walanus. For scales: see fig. 2 and 5 a.

Fig. 4. A share of pottery, flint and obsidian finds from house no. 2 of Biskupice site 18. For details: see Table S1.

Fig. **5**. Calibrated ranges for the samples taken from house no. 2 of Biskupice site 18. For details: see Table 1.

Fig. **6**. Bayesian modelling of calibrated dates for the samples taken from house no. 2 at Biskupice site 18.

Fig. **7**. Selected pottery from house no. 2 from Biskupice site 18. Drawings: M. Korczyńska-Cappendberg (a) and R. Kenig (b-h).

Fig. **8**. Examples of pottery sherds and ceramic fabrics of the technological groups from house no. 2 at Biskupice site 18. Photos: R. Kenig (pottery sherds) and A. Rauba-Bukowska (thin-sections). For details: see Tables 5 and 6.

Fig. **9**. Results of the lipid residue analysis from house no. 2 from Biskupice site 18. A) Partial gas chromatogram of a typical lipid extract interpreted as animal fat (BIS7498). Peak identities are: FA n and FA n:i, fatty acids containing n carbon atoms and i double bonds (detected as fatty acid methyl esters); IS, internal standard (*n*-tetratriacontane); b) $\delta^{13}C$ values for the $C_{16:0}$ and $C_{18:0}$ fatty acids prepared from lipid extracts from open bowls (open circles) and spherical bowls (filled circles). The three fields correspond to the P = 0.684 confidence ellipses for animals raised on a strict C_3 diet in Britain (Copley et al., 2003); c) A scheme showing a relationship between types of the vessels and concentration of lipids.

Fig. **10**. Kernel density analysis of flint (a) and obsidian (b) artefacts from house no. 2 at Biskupice site 18.

Fig. **11**. Selected obsidian artifacts from house no. 2 at Biskupice site 18 see Table S5. Photos: D. Werra; Drawings: E. Gumińska.

Fig. **12**. Results of the XRF analysis of obsidian artefacts from house no. 2 at Biskupice site 18: a) Sr vs. Zr composition of large obsidian artifacts. Symbols plot the artifacts listed in Table S6; b) Normalized Rb/Sr/Zr composition of small obsidian artifacts. Symbols plot the artifacts listed in Table S7. Dashed lines depict the range of composition variation measured in archaeologically significant geological reference samples (adapted from Hughes and Werra, 2014: fig. 4 and 5).

Fig. 13. Directions of Transcarpathian influences to the LBK settlement at Biskupice site 18.

Table 1. Results of the radiocarbon dating of samples taken from house no. 2 from Biskupice site 18.

Table **2.** Percentage number of samples assigned to each fabric type at Biskupice site 18 and during all phases of LBK sites from the territory of Lesser Poland (*n* = 302). Technological groups after Rauba-Bukowska and Czekaj-Zastawny, 2020.

Supplementary material

Table S1. Pottery, flint and obsidian finds from house no. 2 of Biskupice site.

Table **S2**. Results of the petrographic analysis of the pottery sherds from house no. 2 from Biskupice site 18.

Table **S3**. **Results of the petrographic analysis of the pottery sherds from house no. 2 from Biskupice site 18; red - reducing firing; redox - reducing firing with small inflow of air; ox - oxidizing firing.**

Table **S4**. Results of lipid residues analysis: Potsherd sample details and results for sherds from house no. 2 from Biskupice site 18.

Table **S5**. Technological and morphological description of obsidian artefacts from house no. 2 at Biskupice site 18.

Table **S6**. EDXRF Composition Estimates for Large Obsidian Artefacts from house no. 2 at Biskupice site 18.

Table **S7**. Integrated Net Peak Intensity Data for Small Obsidian Artefacts from house no. 2 at Biskupice site 18.

Highlights

Biskupice site (S Poland) represents the late Želiezovce phase (5300 to 5000 BC)

Pottery was produced locally, and showed a use of animal fats for cooking

The face vessel was of local origin, but influenced by Transcarpathian style

Obsidian artefacts originated from the Carpathian 1a/1b chemical type, S-E Slovakia

Transcarpathian contacts between LBK and Bükk culture were discussed

An Early Neolithic House in the Foothills: A Case Study of Pottery and Lithic Artefacts from the Biskupice Site 18 (Wieliczka Foothills, Southern Poland)

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Abstract

The paper presents a comprehensive analysis of pottery and lithic materials found in archaeological features associated with an Early Neolithic house from Biskupice (southern Poland) to shed light on exchange networks of the first farmers in Central Europe. The research began with the discovery of a unique fragment of a face vessel made in the Želiezovce style, a motif primarily found in Moravia and north-eastern Austria. Therefore, specialised analyses were undertaken to determine whether the Biskupice fragment was locally produced or originated from areas south of the Sudetes and Carpathians. The study involved an examination of raw clay material and the technology used to create the anthropomorphic vessel, aiming to establish its provenance (local production *versus* import). Petrographic methods were employed to analyse a diverse group of vessel types for comparison. Additionally, a selected group of pottery fragments, including the face vessel, underwent lipid residue analysis to determine their potential use. The combination of microscopic examinations and lipid residues analysis was utilised to study the link between the physical properties and function of the vessels. Finally, the archaeological context of other artifacts from the same house, including lithic assemblages, was investigated to determine the presence of both local and imported raw materials in Biskupice. The main conclusion of the study indicates local production of pottery, including the face vessel, and lithic implements. Conversely, a Transcarpathian transfer of some technological and decorative ideas, as well as imports of raw material such as obsidian, were confirmed.

Keywords: Linear Pottery culture, Early Neolithic, Želiezovce phase, petrographic analysis of pottery, lipid residue analysis, lithic analysis

1. Introduction

During archaeological excavations conducted in 2020 in Biskupice, southern Poland, a vessel depicting a human face with horn-liked protrusions was discovered in a feature associated with a house belonging to the Linear Pottery culture (abbreviated as LBK, from

German *Linearbandkeramik*). This archaeological unit is roughly dated to the second half of the sixth millennium BC. Anthropomorphic vessels and figurines referred to the Early Neolithic in Poland are extremely rare (Czerniak, 1998, fig. 6; Dębiec, 2014; Czekaj-Zastawny, 2014, fig. 39), making this find particularly noteworthy. The stylistic motifs of the vessel from Biskupice were already analysed taking into account all other human representations from European LBK sites and those coming from the Alföld Linear Pottery culture. The comparison of 130 face vessels revealed a strong connection between the pot from Biskupice and the Želiezovce style, typical of the late phase (III) of LBK (Korczyńska et al., 2021). The Želiezovce style is primarily found in south-western Slovakia, where a separate Želiezovce group or even culture was distinguished, divided into phases and subphases (as Želiezovce I, IIa, IIb and III; Pavúk 1969; 1994). In Poland, it is territorially limited mainly to the Upper Vistula River Basin (Czekaj-Zastawny, 2017) including the Carpathian Foothills (Valde-Nowak, 2014; Czekaj-Zastawny et al., 2021). Therefore, this new find from Biskupice indicates chrono-cultural connections with areas located south of the Carpathians.

The artefact in question was discovered in feature no. 25, which is part of the well-preserved house no. 2. This long house with a post construction is typical of the LBK. The exceptional nature of the face vessel finding prompted the research team to attempt to analyse and interpret in detail its archaeological context, i.e., house no. 2, before completing a comprehensive investigation of the entire settlement. Therefore, this study only presents the analysis of the features and materials found in one of four possible houses discovered during recent excavations in Biskupice. Additionally, there is evidence of another house of the same chronology found on the highest part of the elevation on which the settlement was situated. It was excavated partially for rescue reasons before 2020 (Czerniak, 2014, unpublished). Currently, the settlement is divided by a road and therefore, it is impossible to trace a relationship between house no. 2 and other household units, the internal organization of the settlement and the chronology of all the households. The full extent of the settlement is difficult to evaluate due to the unsuitability of non-destructive methods due to the characteristics of the soil condition and the presence of modern buildings in the north-western part of the site (Moskal-del Hoyo et al., 2022, unpublished). Early Neolithic artefacts found during the surface survey suggest that this area may not have been very large, between 0.5 and 1 hectares. Nevertheless, based on the local geomorphology and current field research, it is likely that the settlement was composed of a small group of households.

Archaeological settings

The site at Biskupice is situated on a loess-mantled hummock (approximately 312 m.a.s.l.), delimited by two streams (Korczyńska et al., 2021). It is located in the Wieliczka Foothills, which belong to the belt of Carpathian Foothills (Kondracki, 1998). The site is part of the Early Neolithic settlement zone in southern and south-eastern Poland, specifically within the settlement cluster connected with the loess landscapes in the Upper Vistula River Basin (Fig. 1; Czekaj-Zastawny, 2009). These landscapes also cover regional sections of Carpathian Foothills (Fig. 1; Valde-Nowak, 2014; Czekaj-Zastawny et al., 2020). The site was identified through systematic field surveys (the Polish Archaeological Record; in Polish: Archeologiczne Zdjęcie Polski, abbreviated as AZP), but the first remnants of LBK settlement appeared during a rescue excavation (Czerniak, 2014, unpublished). The unique location of the LBK site in the foothill zone was one of the significant factors that led to the initiation of new excavation works in 2020. Another noteworthy feature of the site, confirmed by the excavation, was the presence of materials typical of only one occupation phase (LBK), providing optimal conditions for a case study on Early Neolithic occupation. This approach helps avoid the problems of post-depositional disturbances and mixing of archaeological materials that typically occurs in multiphase sites.

During two archaeological campaigns (2020 and 2021), remains of at least four LBK household units were uncovered (Fig. 2). Only one of the houses – house no. 2 – was discovered in its entirety. Its remains included 37 remnants of posts arranged in five rows and four lateral pits. Two of the pits were located along the western wall (features nos. 23 and 24), and two were localized along the eastern wall (features nos. 20 and 25). The house was oriented on a north-south axis, and its size might be estimated at approximately 6 m x 11 m. All four elongated pits, situated outside the outer walls along the longer axis of the house, had oval, orthogonal shapes. Their dimensions varied between 1.2 – 2.2 m on the longitudinal axis and 2.7 – 4.3 m on the later axis, with maximum depths ranging from 0.35 m, to 0.9 m (Fig. 3). All four were characterized by irregular bottoms, and their fill contained a sequence of loessic inclusions and cultural layers that differed in colour and consistency of the sediment. Considering the division proposed by P. J. R. Modderman (1986, Fig. 29), this house represents Type 2 (with one corridor on the north side). This type of relatively small house is not typically discovered at LBK settlements, although a similar construction was detected at the site Brzezie no. 17, a few kilometres northeast of Biskupice (Czekaj-Zastawny, 2009; Czekaj-Zastawny, 2014).

All the elongated pits yielded pottery fragments, flints, obsidians and some small daub fragments (Fig. 4, Table 1S). As mentioned earlier, the most spectacular finding associated with this house is the face vessel deposited in the elongated pit no. 25 (Korczyńska et al., 2021). In addition, this pit contained 408 mostly undecorated pottery sherds, as well as 368 flint and three obsidian artefacts. The proportions of various types of findings are quite similar to other elongated pits connected to this house, with an exception of feature no. 20, located north to the pit no. 25, which delivered many more lithics, mostly chips. Additionally, two fragments of querns appeared in this feature (Table S1).

In the northern part of the house no. 2, two further pits (features nos. 18 and 22) were discovered. Both had circular, orthogonal shape of approximately 2 m in diameter and elliptical cross-sections. In general, their fill was characterized by a dark-brownish colour. The taphonomy of the sedimentation of both differed from the elongated pits. In the case of feature no. 18, the fill was relatively homogenous. In contrast, the fill of feature no. 22 was clearly laminated, and there were a few stones with signs of heat exposure found within one of the layers. In comparison to the elongated pits, the proportions of the particular types of artefacts differed significantly (Fig. 4, Table 1S). It is challenging to discuss the function of these pits and their chronological relation to the house no. 2. Due to the location of pit no. 22 within the house no. 2, it is presumed that both structures could not be contemporary. On the other hand, the function of feature no. 18 such as a storage pit, cannot be ruled out since this relatively shallow pit contained the highest number of charred plant remains, mostly cereals (Kapcia et al., 2023). Whether this pit was serving the community that lived in house no. 2 remains an open question.

Aims of the study

The specific objectives of the research were, firstly, to provide new AMS dating of the Želiezovce style represented in the Biskupice site. The chronological framework of this phase in Poland is not well established due to a scarcity of archaeological sites with reliable series of radiocarbon datings (Oberc et al., 2022). In south-western Slovakia, the absolute chronology of the Želiezovce phenomenon as a whole, as well as its traditional stylistic sub-phases, is also imprecisely defined, and there is uncertainty of its status (group?, culture?, style?). Secondly, the aim was to determine whether the face vessel from Biskupice represents an import from areas south of the Sudetes and the Carpathians or if it was produced locally. To achieve this goal, the clay raw material and the technology of this pottery fragment were analysed. An important question concerned its function, which was tested with the help of lipid residue analysis. Similar analyses were performed on pottery sherds found in features connected with the same house to provide a context to this exceptional finding. Thirdly, the study aimed to discern further determinants of the Transcarpathian contacts, through analyses of the pottery and lithic artefacts.

2. Materials and Methods

2.1. Radiocarbon dating

A total of 10 samples for radiocarbon dating were selected from features associated with house no. 2. They consist of charred plant macro-remains obtained from archaeobotanical samples collected during the archaeological excavations. For each dating result, one taxonomically identified cereal grain was chosen, considered relevant for obtaining the most accurate dating result (Nowak et al., 2017), from a sample taken from a deep layer of each archaeological feature. Cereal caryopses (n = 9) belonged to emmer wheat *Triticum dicoccon* and/or einkorn wheat *T. monococcum* (Table 1). Additionally, one sample comprised 3 fruits of wild buckwheat *Fallopia convolvulus* (Table 1) as this species is one of the most frequently found wild herbaceous plants at this site (Kapcia et al., 2023) andcould have been used as food. For dating, accelerator mass spectrometry (AMS) at the Poznań Radiocarbon Laboratory was employed, following the methods of chemical pre-treatment (Brock et al., 2010). Calibration was made using OxCal ver. 4.4 (Bronk Ramsey, 2009) with 14C calibration curve IntCal20 (Reimer et al., 2020).

2.2. Pottery

The analysis of pottery fragments was conducted through measurements of their dimensions and weight, along with a description of their state of preservation, technology (evaluated macroscopically), forms, and decoration. The distribution of all pottery sherds found in the features associated with house no. 2 took into account the three-dimensional location of all fragments, which was fixed using a Total Station (model Geomax Zoom 40).

2.2.1. Petrography

A total of 27 fragments of vessels were selected for petrographic studies. These fragments represent macroscopically diversified material both in shape and fabric and were excavated from the elongated pits of house no. 2 (Table S2). The analysis aimed to describe and recognise raw materials and technological features of the ceramic pastes, including admixtures, firing conditions and temperature. One sample (no. 10) came from the face vessel.

Thin sections from the ceramic sherds were analysed under a microscope with polarised light. Using point counting techniques, the relative abundances of certain compounds were established, including clay minerals, quartz, potassium feldspars, plagioclase, muscovite, biotite, carbonates, fragments of sedimentary, igneous and metamorphic rocks, fragments of reutilised ceramics (grog), as well as organic material (Table S3). The description of mineral composition also included silty grains and voids (pores, cavities). The percentage of these elements was established for every sample. The fabric description also included the degree of mixing of the ceramic fabric and the temperature and conditions of the firing process (Reedy, 2008, 109-210; Whitbread, 2017). An approximate temperature of the original firing was determined based on the thermal alteration of clay minerals, specifically the observation of the degree of transformation of a ceramic matrix into an amorphous, isotropic substance, and the observation of biotite minerals, hornblende, and glauconite (Bolewski, Żabiński, 1988; Quinn, 2013: 190-203; Daszkiewicz, Maritan, 2016). The division of grain fractions assumed in this paper followed the determinations formulated by the Soil Science Society of Poland (Polskie Towarzystwo Gleboznawcze, 2009).

2.2.2. Lipid residue analysis

A total of 34 sherds were selected for lipid residue analyses. The samples analysed included fragments from spherical vessels (n = 25), open bowls (n = 4), vessel with neck (n = 1) and pots from unknown typology (n = 2). Two samples associated with the face vessel were also sampled, namely a fragment of the face vessel and another sherd thought to be part of this pot (Table S4).

Lipid residue analyses and interpretations were based on established protocols (Evershed et al., 1990, Correa-Ascencio and Evershed, 2014). Briefly, analyses proceeded as follows: approximately 1 to 2 g ceramic fabric samples were taken, and their surfaces were cleaned using a modelling drill to remove any exogenous lipids (e.g., soil or finger lipids due to handling). The samples were then ground to a fine powder in a glass mortar using a pestle. The powdered sherd was transferred to a glass culture tube, an internal standard added for quantification (n-tetratriacontane, 20 μg) and an acidified methanol solution (H_2SO_4/MeOH, 4 % v/v, 5 mL, 70 °C, 1 h) was added. The lipids were then extracted from the aqueous phase with hexane (2 x 3 mL plus 2 x 2mL). The solvent was evaporated under a gentle stream of nitrogen to obtain the total lipid extract (TLE). Aliquots of the TLE (generally one quarter aliquots) were trimethylsilylated using *N,O*-bis (trimethylsilyl) trifluoroacetamide containing 1 % trimethylsilyl chloride (20 μL, 70 °C, 1 h) and re-dissolved into hexane for analysis by gas chromatography (GC-FID).

Combined GC-MS analyses were also performed on trimethylsilylated aliquots of the lipid extracts enabling the elucidation of structures of components not identifiable on the basis of GC retention time alone. The samples where animal fats were detected were submitted to GC-combustion-isotope ratio mass spectrometry (GC-C-IRMS) in order to distinguish between non-ruminant and ruminant fats, and dairy from adipose fats (Copley et al., 2003). The detection of potential aquatic biomarkers such as ω-(*o*-alkylphenyl) alkanoic acids and isoprenoid fatty acids were carried out using GC-MS analysis, following on from Cramp and Evershed (2014).

2.3. Lithic analysis

Raw materials used to make lithic artefacts were identified based on the author's experience and comparative collection stored in the ~~IAE PAS~~ Institute of Archaeology and Ethnology, Polish Academy of Sciences in Warsaw and Institute of Systematics and Evolution of Animals, Polish Academy of Sciences in Kraków. The lithic and obsidian artefacts were classified into four morphological groups following Lech (2012) and Werra et al. (2021). Among the lithic finds, 16 obsidian artefacts were detected during the archaeological excavations (Table S5), while 40 small items, mainly small chips, were found after wet-sieving of archaeobotanical samples (in the heavy fraction; mesh of 1 mm). Observations on flint assemblage were carried out on 861 items recorded during archaeological excavations.

2.3.1. XRF- analysis

All the 14 obsidian artifacts recovered from house no. 2 were analysed by using energy dispersive x-ray fluorescence (EDXRF) to determine their trace and selected minor element compositions. The derived chemical composition profiles were then compared with those of known obsidian sources to determine the most probable parent geological source for each artefact (i.e., artifact-to-"source", including geochemical type/variety attributions; Hughes, 1998)). EDXRF laboratory analysis conditions, instrumentation, geochemical type attribution procedures, element-specific measurement resolution, and literature references applicable to these samples follow those reported for artifacts from Rydno XIII/1959 (Hughes and Werra, 2014) and from other Mesolithic and Paleolithic sites in Poland (Hughes et al., 2018).

3. Results

3.1. Radiocarbon dating

The dating results indicated a chronology pointing toward the end of the sixth millennium BC (Fig. 5; Table 1). All the likelihoods, without any modelling, suggest a fairly long interval, i.e., spanning at least from about 5300 to 5000 BC (Fig. 6a). This does not imply that house no. 2 must have been in operation for 300 years. Instead, it suggests that it was in use for some period within those three centuries. After Bayesian modelling, considering the start and end dates of the 2sigma intervals for the start and end boundaries, respectively (Fig. 6a), the situation remains essentially unchanged. However, when considering the highest probability sections of these boundaries and the calibration curve in the relevant interval (Fig. 6b), the hypothetical timeframe for the functioning of house no. 2 shrinks to approximately 5200-5050 BC. Similarly, it cannot be argued that house no. 2 was occupied during the whole of that time.

3.2. Pottery analysis

More than 1100 pottery sherds were discovered in features connected with house no. 2. Their distribution was uneven, with a high concentration in the elongated pits on both sides of the house (features nos. 23 and 25). In contrast, in the south-western elongated pit (no. 24) and in one pit interpreted as a storage pit (no. 18), and post-holes, a smaller number of sherds were found. For 248 fragments, it was possible to reconstruct the form of the vessel. More than 75% of this assemblage is dominated by open bowls with varying degrees of walls eversion and spherical vessels. Vessels with a high neck appeared sporadically, while only one miniature vessel was found. The majority of the pot fragments are ornamented, especially with engraved lines, such as arched and paralleled (Fig. 7c and e). They are accompanied by notches, some of them quite long, crossing a few lines (Fig. 7g and d). Other motifs were recognised, including simple cuts, especially under the rim. The pots were frequently decorated with plastic elements, such as knobs and clay bands (Fig. 7f). Some of the sherds contain both kinds of ornament: engraved lines and plastic knobs (Fig. 7h), observed in fine and coarse ware. Also, finger and nail imprints occur as a part of decoration. Anthropomorphic, such as the face vessel (Fig. 7a), and zoomorphic motifs are very rarely found. The latter one is represented by a handle with a plastic decoration that resembles a head of an animal (Fig. 7b).

3.2.1. Petrography

Petrographic analyses of pottery fragments from house no. 2 have shown that the mineral composition of the ceramic masses includes components such as sandstone, mudstone and claystone (Table S2). The most common are silty clays (clay with an abundant quantity silty grains). Such clays are among the most available in the study area. Various admixture types were added to the clay, such as grog, sand and plant temper, perhaps depending on the pottery function.

To be more specific, six technological types are represented (Table S3, Fig. 8; Rauba-Bukowska et al. 2007; Rauba-Bukowska, 2014a; 20014b; Rauba-Bukowska, Czekaj-Zastawny, 2020). Most of the sherds were associated with technological types VI and VII, forming 59% of the assemblage (Fig. 8m-s) representing fine, medium and thick-walled pottery. The main components of ceramic fabric of type VI are clay minerals, silty grains and coarser grog fragments (Fig. 8m-o, grog shown with an arrow). The type VII (Fig. 8p-s) is similar to VI but, apart from grog, it contains sand admixture, while the main components of raw material are clay minerals, grains of quartz, feldspar, and fine mica flakes. Rare are heavy minerals and chalcedony. Technological type II is also common in this assemblage (19%) which represents a thin-walled pottery (fine ware; Fig. 8d-f). The main components of raw material are clay minerals, silty grains, and very fine mica flakes. Within fine-grained clay, microfossils of plankton appeared. Other technological groups were found infrequently in ceramic assemblages. The main components of the ceramic pastes of type I (Fig. 8a-c) are clay minerals, grains of silty fraction, fine mica flakes and iron oxides and hydroxides concentration. Pots made of paste type III (Fig. 8g-i) consist of clay minerals, poorly sorted quartz grains, feldspars and chalcedony grains. Rounded fragments of sedimentary (e.g., mudstone) or metamorphic (e.g., quartzites) rocks are present. The ceramic fabric of type IV (Fig. 8j-l) is characterized by lumpy structure and bigger porosity, caused by poorly mixed clay with fragments of sedimentary rocks, mostly claystone, mudstone and sandstone. The main admixture consists of plant fragments which, after destruction during firing, caused porosity. The face vessel represents type VII (Fig. 8p-s) and has ceramic fabric, which is medium to coarse grained with numerous sand grains and grog fragments. The raw material is silty clay with sand, composed mostly by quartz, feldspars and rarely quartzites.

3.2.2. Lipid residue analysis

A total of 17 sherds (50%) were dominated by $C_{16:0}$ (palmitic) and $C_{18:0}$ (stearic) fatty acids and interpreted as archaeological animal fats (Fig. 9). High concentrations of $C_{18:1}$ unsaturated fatty acids were present in six of these sherds likely indicating that these fats are not archaeological in origin (Whelton et al., 2021). The presence of cholesterol in some of these extracts also points towards modern contamination (Hammann et al.,2018). Those lipid extracts were not characterised further. Unfortunately, none of the sherds associated with the face vessel provided interpretable archaeological fats. Of the 11 sherds where archaeological animal fats were clearly identified, the main $C_{16:0}$ and $C_{18:0}$ fatty acids were accompanied by odd-carbon number fatty acids, biomarkers of bacterial populations from the rumen and characteristic from ruminant fats (Fig. 9a; Keeneyet al., 1962). Concentration of lipids in those sherds ranged between 6 µg and 4.16 mg per g of sherd (mean: 900 µg g^{-1}) (Table 3). The determination of animal fat types was achieved by measuring the $\delta^{13}C$ values of the main fatty acids ($C_{16:0}$ and $C_{18:0}$). The $\delta^{13}C_{16:0}$ values of lipid extracts ranged from -28.4 to -25.6‰ and were consistent with non-ruminant adipose fats (n = 4) and mixtures between non-ruminant and ruminant adipose fats (n = 7, Fig. 9b; Copley et al., 2003). The archaeological animal fats extracted from the coarse open bowls (n = 3) were all consistent with non-ruminant adipose fats; while spherical vessels displayed a wide range of animal fats, from non-ruminant adipose fats, to various mixtures of non-ruminant and ruminant adipose fats (Fig. 9c). No ω-(*o*-alkylphenyl) alkanoic acids were detected in the extracts; and 4,8,12-trimethyltridecanoic acid (TMTD) was detected in only one extract, suggesting very little evidence for the processing of aquatic resource in the pottery studied here (Table S). This can be in accordance with local landscape as the site is not located in close proximity to water reservoirs.

3.3. Lithic material

In archaeological features connected to house no. 2, a total of 877 lithic artefacts were detected during archaeological excavations. The majority of them (861 pieces) are made of flint, while the remaining ones are of obsidian (n = 16). Flint artifacts were mostly found in the fillings of two features (nos. 23 and 25; Fig. 10a). They mostly represent debitage and only 50 of them are implements (retouched tools and flint hammerstones). Concerning the flint assemblage, almost all specimens were made of mezo-local Jurassic-Cracow flint (95.3%), originating from outcrops located north and north-west of Kraków. Some flint items (1.7%) were burned, and only two were made of so-called chocolate flint (0.2%), from either the north outskirts of the Holy Cross Mts. (ca. 170 km north-east of the site) or the central part of the Kraków-Częstochowa Upland (ca. 100 km north-west of the site; see Sudoł-Procyk et al. 2021).

A total of 15 items of flint artifacts belong to the first morphological group (natural nodules and cores) as defined by Lech (2012). These are primarily a blade cores with a single striking platform formed by single blow. Generally, cores have cortical sides, without traces of preparation and signs of faceting. The striking platform mostly is located on the narrow side of the core, but in a few cases on the wider side. The size of cores varies greatly, with length from 28 to 70 mm, width from 21 to 62 mm, and thickness from 23 to 48 mm. The cores are used up, often to residual forms or reused as hammerstones. The main purpose was to obtain blades, which were then the basis for the production of tools. The second group consists of 156 whole blade and their fragments, including 60 with a cortical surface. The third group (flakes and waste) is the most numerous – 603 items, including 148 cortical flakes and 141 chips. The fourth and last group, implements, includes 50 artifacts. Most of them are retouched blades and their fragments ($n = 23$), endscrapers ($n = 9$) and hammerstones ($n = 10$). Only four truncations, three retouched flakes and one perforator were registered.

Obsidian artifacts were found sporadically in six features, and the majority of them appeared in feature no. 23 (Fig. 10b). The short descriptions of each morphological group of obsidian artefacts appear in Table S5. The first group (natural nodules and cores) contains one item, a blade core, with a striking platform formed with the detachment of a single flake, showing signs of faceting, trace of preparation on the tip, but not on the sides (Fig. 11i). The second group consists of one whole blade and six blade fragments (Fig. 11a-d, g-h). The third group of eight artefacts comprises four flakes and four waste pieces (two of them were not geochemically analysed; Fig. 11e-f). Also, 40 items from archaeobotanical samples represent this group. No items were classified in the fourth and final group (implements).

3.3.1. Geochemical analysis of obsidian

The results of the quantitative geochemical analysis of large artifacts appear in Table S6, data for smaller specimens are listed in Table S7, and are illustrated graphically in Figure 12. The Sr/Zr data for eight specimens large enough for quantitative analysis (Table 6 and Fig. 11a, d-f, i) plot within the range established for Carpathian 1a/1b obsidians (Rosania et al., 2008) erupted in the Zemplén Mountains of southeast Slovakia (Fig. 12a). The other six obsidian specimens (Fig. 11:b, c, g, h) were too small and thin to generate x-ray counting statistics adequate for proper conversion from background-corrected intensities to quantitative concentration estimates (i.e., ppm), so they were analyzed to generate integrated net count (intensity) data for the elements Rb, Sr, Y, Zr, Nb, Fe and Mn (see Hughes, 2010 for analysis protocol). Background-subtracted intensities (counts per second) were converted to percentages, and source (geochemical type) assignments were made by comparing the plots for various element intensity ratios determined on artifacts against the parameters of known source types identified in Central Europe. Integrated net peak intensity data (Table S7, Fig. 12b) indicate that all six small flakes also were made from Carpathian 1a/1b obsidian.

4. Discussion

Chronology of the settlement at Biskupice

The nature of the ornamentation of the vessels from Biskupice indicates a classic, second stage of the Želiezovce phase of the LBK (Pavúk 1969; 1994; Kadrow 1990; 2020) with medium or long notches that intersect several thin and V-shaped lines. Several motif variants can be listed here. The most common are double, triple arc lines with intersecting notches, and multiple horizontal and diagonal straight lines. In addition, there are elements indicating a late sub-stage of the phase Želiezovce II, i.e., phase IIb (Pavúk 1969: Fig. 6; Kadrow 1990, 2020: 147; Dębiec, 2014: 226). They are characterized by very long notches, crossing even five or six lines of engraving. Only thin-walled spherical vessels and open bowls are decorated with engraved lines. In the area of south-western Slovakia, materials corresponding stylistically and chronologically to the Želiezovce IIb subphase occurred at many sites, such as Štúrovo (Pavuk, 1994), Bajč (Cheben, 2000), and Vráble (Furholt et al., 2020).

Among plastic decoration, there is a quite uncommon find of a handle that resembles a head of an animal (Fig. 7b). This kind of handles belongs to Type no. 2 (following Becker, 2007) and they are spatially and chronologically associated with the Želiezovce phase of the LBK (Becker, 2007: 23-24). Although some examples are known from western Germany, Austria and Czech Republic, there is a very distinct cluster of such pots in Moravia, south-western Slovakia, and north-western Hungary. The most similar analogies, due to the horizontal perforation in the handle, might be found in an assemblage of such handles from the settlement at the Danube valley in Mužla-Čenkov, okr. Nové Zámky (Kuzma, 1990: 441, figs. 13,31-32; 443, figs. 15,42). It is unclear what kind of animal is represented. Some scholars have indicated *bovidae* (after Becker, 2007:23), but in most cases, a convincing attribution is not possible.

To sum up, pottery from Biskupice correspond to the end of the LBK development in south-eastern Poland. Data available in a few sites located near Kraków and Rzeszów (Czekaj-

Zastawny, 2014: 103-105) clearly indicate that the youngest LBK settlements fall on the Želiezovce IIb phase (Pavúk, 1969), after which this culture disappears and a hiatus is observed between the LBK and the next Neolithic unit (Czekaj-Zastawny, 2017). In Biskupice, the series of radiocarbon dates showed an existence of a plateau, although they indicated that the end of house no. 2 might have been situated around 5050/5000BC. In general, this corresponds to the radiocarbon dates acquired for the Želiezovce phase for Poland (Oberc et al., 2022).

Characteristic features of the pottery from Biskupice: local products versus *imported items*

Geological outcrops of Carpathian Flysch (Sub-Silesian Series) and Miocene sediments can be found in the neighbourhood of Biskupice (Burtan, 1954). The mineral and petrographic composition of the studied ceramic pastes are consistent with local geology, as components such as sandstone, mudstone and claystone come from Carpathian Flysch. Additionally, the presence of microfossils like plankton remnants points to local clay from marine Miocene sediments of the Carpathian Foredeep. Neolithic ceramic pastes containing microfossils or glauconite grains are known from a few sites near Kraków and Wieliczka, showing local sourcing of the raw material (e.g., Modlniczka site 5, Targowisko site 16; Rauba-Bukowska 2019; 2021). Pottery fragments that have been studied in detail show that the ceramic vessels from the site are made of local clays with an admixture of sand, grog and organic fragments. Furthermore, ceramic fabrics from Biskupice, as well as from other sites in Lesser Poland (Rauba-Bukowska, Czekaj-Zastawny, 2020) due to the addition of grog, show similarities to ceramic masses of the Bükk culture (Kozłowski et al., 2015; Czekaj-Zastawny et al., 2018).

The diagnostic features of the technology of pottery and the predominance of VI and VII technological types (59%) confirms late chronology of the Biskupice pottery assemblage (Želiezovce phase, see: Table 2) (i.a., Pavúk, 1969, fig. 6; Kozłowski et al. 2014; Kadrow and Rauba-Bukowska 2016; 2017; Czekaj-Zastawny et al., 2017; Moskal-del Hoyo et al., 2017; Kadrow, 2020, 147; Rauba-Bukowska, Czekaj-Zastawny, 2020). It was noticed that there was a significant change in the preparation of ceramic pastes in the LBK between the Music-Note (classical) and Želiezovce (late) phases (Rauba-Bukowska, Czekaj-Zastawny, 2020; Rauba-Bukowska, 2021). It consists of several changes in the composition of the ceramic masses. First, a new type of admixture appeared, namely chamotte (grog; types VI and VII; Table S5), as fragments of sedimentary rocks were a component of ceramic masses in the olde and classical phases. Fabrics with an admixture of clay pellet were called type IV (Rauba-Bukowska et al., 2007; Rauba-Bukowska 2014, 2021; Rauba-Bukowska, Czekaj-Zastawny, 2021). These pastes were mainly used to make larger, coarse, thick-walled pots.The second significant change in the technology between ceramics of the Music-Note and the Želiezovce phase was the increasingly rare use of an organic admixture, consisting mostly of chaff fragments from domesticated cereals (Moskal del-Hoyo et al., 2017). This temper was very common in the older and classical phases of the LBK and was present in all types of ceramic fabrics, but more often was found in masses of type IV of thick-walled vessels. Plant fragments were also added to the clay in the Želiezovce phase, but without a clear correlation as to the type of ceramic mass.

Regarding firing conditions and temperatures, there have been almost no changes in this technological field during LBK period in Lesser Poland (e.g., Rauba-Bukowska et al. 2007; Rauba-Bukowska 2014; Kozłowski et al. 2014/2015; Rauba-Bukowska 2021). Firing usually took place in an atmosphere with a weak supply of air at temperatures around 650-800°C and rarely over 800°C. A similar structure of the method of firing is constant for the entire LBK and probably also for other Neolithic cultures, e.g., the Malice culture (Rauba-Bukowska et al. 2007; Rauba-Bukowska 2021). The collection of pottery from Biskupice studied here (*n*=27) does not differ from this scheme; firing prevails with a small supply of air at temperatures of 700-800°C.

The face vessel and the pottery with the zoomorphic handle (samples 10 and 25) show characteristic features of local ceramic paste, thus representing local production. This demonstrates that the idea of depicting anthropo- or zoomorphic representation was transferred from Transcarpathian areas rather than the vessels being imported. Similar cases were recently observed among LBK assemblages. For example, a study of an anthropomorphic figure from Kosina, showing a high similarity with the human figures from the Alföld Linear Pottery culture, was made of local clay (Dębiec et al., 2021).

Pottery use

Lipid residue analysis of pottery samples from Biskupice showed that animal fats were present, coming from ruminants and non-ruminants. Animal bones are not preserved at the site due to soil acidity, and thus lipid residue analyses provide a rare glimpse into animal management at the site. Ruminant fats are commonly found in LBK pottery, especially in northern area of its distribution such as the Kuyavia region, while non-ruminant adipose fats were rarely detected (Salque et al., 2013; Roffet-Salque et al., 2019). In one of the more comprehensive studies on lipid residues in the LBK pottery in Bylany (Czech Republic), ruminant adipose fats also predominated, whereas non-ruminant adipose fats were uncommon (Matlova et al., 2017; Brychova et al., 2020). The analysis of lipid residues from Biskupice did not demonstrate the presence of dairy products in the samples. No sieve pottery was found in this settlement, which is in line with southern and eastern Poland from where sieve pottery fragments appeared only at two archaeological sites at Gwoździec site 2 (Robson et al., 2021) and Puławy-Włostowice (Szeliga, 2018), but no finds are known from the Upper Vistula River settlement clusters. This gap in southern Poland is to be noted and can be observed on a map showing the distribution of sieve pottery in Central Europe (Saile et al., 2022, fig. 16).

Lipid residue analysis from Biskupice demonstrated that spherical vessels and open bowls of coarse ware were used to process animal carcass products. Although thin-walled pottery contained high concentrations of archaeological lipids, in Biskupice, the highest recovery rate was in coarse ware, which may suggest that vessels made of such fabric, were used especially for cooking. Similar observations were given in the case of a long-term LBK site 7 in Ludwinowo (Kuyavia, Poland), in which a comprehensive study of lipid residues analysis was conducted based on a large group of pottery sherds (*n* = 513). According to this study, coarse ware vessels were better adapted to cooking or it is possible that these kinds of pottery gave a high recovery rate and lipid concentration due to the fact that the lipids are preferentially absorbed in such a fabric compared to thin-walled vessels (Roffet-Salque et al., 2019).

Lithic industry: local raw material versus *imported*

The lithic industry was almost entirely based on local raw materials withJurassic-Cracow flint clearly dominating. This is not surprising, as Jurassic-Cracow flint prevails on LBK sites in southern Poland and was noted in 95% of all lithic assemblages. Obsidian, which is mostly represented by blanks and isolated cores, also occurred at almost all LBK sites in Lesser Poland. It is very exceptional in the early phase, sporadic in the middle phase and quite common in Phase III (Szeliga, 2009). In Biskupice, among raw materials other than Jurassic-Cracow flint obsidian prevailed, although it played a marginal role, accounting for less than 2% of the lithic assemblage. Similar proportions were observed in the Upper Vistula River valley at Brzezie site 17 (Wilczyński, 2014) and other sites in Lesser Poland in Želiezovce phase (e.g., Kaczanowska et al., 1987; see also Szeliga, 2009), where only at two sites obsidian share exceeded 10% (Kraków-Nowa Huta Krzesławice site 41; Godłowska, 1982) and 19%

(Gwoździec; Wilczyński and Kufel-Diakowska, 2021). On the other hand, in south-eastern areas of Poland, the share of obsidian was usually higher, around 10-20% (e.g., Rzeszów site 16; Kadrow, 1990; Zwięczyca site 3; Dębiec, 2014).

EDXRF data documented that all studied obsidian artefacts analysed from house no. 2 were manufactured from volcanic glass of the Carpathian 1a/1b chemical type, originating from southeast Slovakia on the borderland with northeast Hungary. Imports of obsidian in Lesser Poland seem to be related with areas of the Šariš Basin, Košice Basin, and East Slovak Lowland, where northern branches of the Tiszadob-Kapušany group and the Bükk culture developed, as confirmed by the imports of pottery (Kaczanowska and Godłowska, 2009; Czekaj-Zastawny, 2014, 2017). However, in Biskupice, the presence of cores, flakes and waste material, together with a group of tiny chips found in sediment samples (taken for archaeobotanical research), showed that it was raw material that was imported and then processed locally rather than the finished product. Geochemical analysis conducted on Neolithic obsidian artifacts from Poland also supports the dominance of the Carpathian 1a/1b obsidian variant (Kabaciński et al., 2015; Szeliga et al., 2019).

It is worth mentioning that in neighboring Czech Republic, Slovakia and Hungary, Carpathian1 obsidian also predominated at Neolithic sites, with only a minor representation of the Carpathian2 variant (Elburg et al., 2002; Biró, 2014; 2018; Constantinescu et al., 2014; Burgert et al., 2016; 2017; Riebe, 2019; Furholt et al., 2020; Werra et al., 2021). As Biró (2014: 64, fig. 13) has observed, obsidian of the Carpathian 1 chemical type seems to have been the most important volcanic glass used by prehistoric communities in East-Central Europe. The results from house no. 2 in Biskupice are consonant with this generalization.

Transcarpathian contacts

The analysis of pottery and lithic items from Biskupice essentially indicates the use of local materials. The majority of lithics were made from local flint, whereas obsidian artefacts were imported. Pots were produced from clays of local origin, although their technological and stylistic features are related with cultural influences from the areas located south of the Carpathians. Decorative motifs show patterns observed in the Želiezovce group, while the usage of grog in clay masses is typical for the Bükk culture. However, among vessels found in house no. 2 there are no sherds with decoration known from the Bükk culture, which is quite surprising as this kind of pottery is often associated with obsidian finds. Such a situation is observed, for example, at Vráble, where obsidian finds, coming from the sources located in the eastern Slovak

Carpathians, were found together with Bükk-style pottery sherds, based on the exchange with groups inhabiting the eastern Slovakia (Furholt et al., 2020).

Generally speaking, it should be emphasised that numerous fragments of vessels ornamented in the Eastern Linear styles have been found in Lesser Poland. They can be found in almost every LBK settlement excavated. Some of them were original forms that came from beyond the Carpathian Mountains. In some cases, however, analyses of the ceramic masses revealed the presence of imitations of imported vessels, i.e., locally produced vessels were decorated in the Eastern Linear styles (Czekaj-Zastawny, Rauba-Bukowska, 2014; Kadrow, Rauba-Bukowska, 2016; Czekaj-Zastawny et al., 2017; Dębiec et al., 2021), which isan excellent example of the exchange of ideas between the LBK and ALPC communities (Czekaj-Zastawny et al., 2017).

Based on pottery studies, it is possible to identify more precisely the areas from which imports flowed (Fig. 13). These include the Šariš Basin and the East Slovak Lowland, from where vessels characteristic of the Tiszadob-Kapušany group arrived almost from the beginning of the Music-Note phase of the LBK. In turn, in the Želiezovce phase, vessels of the Bükk culture were imported (Czekaj-Zastawny, 2014; Rauba-Bukowska, 2014). To date, a total of several dozen sites with Eastern Linear imports have been recorded in Poland (Kaczanowska, Godłowska, 2009; Czekaj-Zastawny, 2017, 52-55; Werra, Sobkowiak-Tabaka, 2017; Szeliga, Zakościelna, 2019). The intensification of contacts with the south is noticeable on LBK the territories in south-eastern Poland, especially from the end of the Music-Note phase (Godłowska 1976, 89-92; 1982; Kaczanowska, Godłowska, 2009; Kadrow, 1990).

The contacts with the Eastern Linear complex, although definitely weaker, reached much further than the Upper Vistula Basin - e.g., Upper Silesia. It is believed that some imports came here via the Lesser Poland groupings of the LBK. Ceramics from beyond the Carpathian Mountains took a similar route as far as the Polish Lowlands, including Kuyavia and Chełmno Land (Pyzel, 2009; Czekaj-Zastawny, 2017; Werra, Sobkowiak-Tabaka, 2017).

Analogous relationships can also be observed in other LBK areas, such as the area of the Szécsény Hills in the Nógrád Basin at the northern part of Cserhát Mountain and Ipoly Valley. There it was found that the Ipoly and Zagyva rivers served as important transport routes in the Early Neolithic. Ceramic and stone materials from Szécsény-Ültetés and several other investigated sites in the region indicate exchange with groups to the east, west and south, including Bükk, LBK, Vinča and Szakálhát (Fábián et al. 2016).

After the turn of the 6th and 5th millennia BC, with the disappearance of the LBK and Bükk culture, if viewed from a ceramic perspective, these contacts appear to have ceased as remains of imported southern vessels in the upper Vistula basin disappeared (Czekaj-Zastawny, 2017). However, if the non-ceramic perspective is taken into account, such contacts continued to function. Among other things, one observes an even more intensive influx of obsidian in the first half of the 5th millennium BC, visible above all in the early Lengyel-Polgár complex communities.

The presence of obsidian in Biskupice backs the thesis of the existence of long-distance connections between different “Linear” communities (Fig. 13; Lech, 1989; Wilczyński, 2016). The conveyance of artefacts made of obsidian could take various forms, from direct access, and mobility through trade, exchange, personal individual contact, among others. However, it is not possible to definitively determine how the exchange and contacts between Neolithic communities looked like, although some hypotheses were formulated and possible routes in the Western Carpathians were indicated (e.g., Valde-Nowak, 2009; Pelisiak, 2018). Due to the approximately 220 km distance from the deposit, direct contact with local groups cannot be ruled out. At the same time, the down-the-line exchange model cannot be excluded. It should be noted, of course, that this model likely included various combinations with other models proposed by Colin Renfrew (1975). Depending on the time and location, combinations could vary (see Kreig et al., 2023).

Obsidian in Biskupice, similarly to many other LBK sites, could probably be not only of economic importance (see Szeliga, 2021). “Foreign”/“exotic” items obtained from outside the family zone could have served a prestigious role, functioned as symbols, or as elements that indicated belonging to a specific community (Chapman, 2007).

5. Conclusions

A total of 10 samples, based on cereal grains and wild buckwheat fruits, from house no. 2 provided radiocarbon dating results. Their calibrated ranges show quite a long interval, pointing to dates between 5300 to 5000 BC. These results do not help in discerning a chronology of a use of this house and therefore do not shed light on the precise timeframe of the Želiezovce group in southern Poland. However, the existence of such decorative motifs as, for example, long notches crossing various lines, indicate that the Biskupice site can be one of the youngest settlements of this phase north of the Carpathian Mountains.

The petrographic analysis of the face vessel and a zoomorphic vessel from Biskupice have shown that they were produced locally. A study of the pottery assemblage from house no. 2 has not demonstrated the presence of any other vessel that could be treated as an import. This has been confirmed by a study of group of pottery sherds, which represented six technological types, as all of them have showed a use of local fabrics. Interestingly, the motifs of decoration are of Transcarpathian origins, suggesting that the ideas were transferred, mostly from the area of the Želiezovce group, but pottery items themselves were produced locally. On the other hand, among the lithic assemblage it has been demonstrated that obsidian was imported from sources extracted in the mountains located in present-day territory of south-eastern Slovakia. Although the share of obsidian artefacts is rather low, due to the presence of debitage, it can be concluded that the raw material was imported, and it was processed at the settlement. This observation confirms long-distance Transcarpathian connections between various groups of LBK communities.

Unfortunately, the face vessel has not given any evidence of lipid concentration, and therefore it is still difficult to speculate if it was actually used as container for storing or processing plant or animal remains. The analysis of lipid residues of selected groups of pottery sherds has demonstrated that animal fats from ruminant and non-ruminant were used for cooking at the settlement. Also, a use of aquatic animals has been confirmed. This is especially important as animal bones have not been preserved due to soil conditions, and it gives additional information about food processing and animal husbandry.

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References:

Becker, V., 2007. Rinder, Schweine, Mischwesen: Zoomorphe Funde der westlichen Linearbandkeramik. Habelt, Bonn.

Biró, K.T., 2014. Carpathian Obsidians: State of Art. In: Yamada, M., Ono, A. (Eds.), Lithic Raw Material Exploitation and Circulation in Prehistory. A Comparative Perspective in Diverse Palaeoenvironments. ERAUL 138, Liège, pp. 47–69.
Bolewski, A., Żabiński, W. (Eds.), 1988. Metody badań minerałów i skał. Wydawnictwo Geologiczne, Warszawa.
Bronk Ramsey, C., 2009. Bayesian analysis of radiocarbon dates. Radiocarbon 51 (1), 337–360.
Brock, F., Higham, T., Ditchfield, P., Bronk Ramsey, C., 2010. Current Pretreatment Methods for AMS Radiocarbon Dating at the Oxford Radiocarbon Accelerator Unit (Orau). Radiocarbon, 52, 102-112.
Brychova V., Roffet-Salque, M., Pavlu, I., Kyselka, J., Sedlarova, I., Filip, V., Evershed, R.P., 2020. Defining pottery use and animal management at the Neolithic site of Bylany (Czech Republic). Journal of Archaeological Science: Reports 14, 262-274.
Burgert, P., Přichystal, A., Prokes, L., Petřík, J., Hušková,S., 2016. Původ obsidiánové suroviny v pravěku Čech. Archeologicke Rozhledy 68, 224–234.
Burgert, P., Přichystal, A., Prokes, L., Petřík, J., Hušková, S., 2017. The origin and distribution of obsidian in prehistoric Bohemia. Bulgarian e-Journal of Archaeology 7, 1–15.
Burtan, J., 1954. Szczegółowa mapa geologiczna Polski w skali 1:50000. Arkusz Wieliczka (M34-77A). Instytut Geologiczny, Warszawa.
Chapman J. 2007. Engaging with the exotic: the production of early farming communities in South-East and Central Europe. In M. Spataro and P. Biagi (eds), A short walk through the Balkans. The first farmers of the Carpathian Basin and adjacent regions. Quaderno 12. Trieste: Società per la preistoria i protostoria della regione Friuli-Venezia Giulia, 207-222.
Cheben, I., 2000. Bajč – eine Siedlung der Želiezovce-Gruppe: Entwicklungsende der Želiezovce-Gruppe und Anfänge der Lengyel-Kultur. Universitätsforschungen zur prähistorischen Archäologie, Band 68. Aus dem Seminar für Vor- und Frühgeschichte der Universität Frankfurt. M. Verlag Dr. Rudolf Habelt GmbH, Bonn.
Copley, M.S., Berstan, R., Dudd, S. N., Docherty, G., Mukherjee, A. J., Straker, V., Payne, S. and Evershed, R.P., 2003. Direct chemical evidence for widespread dairying in prehistoric Britain." Proceedings of the National Academy of Sciences of the United States of America 100(4), 1524-1529.
Correa-Ascencio, M., Evershed, R.P., 2014. High throughput screening of organic residues in archaeological potsherds using direct methanolic acid extraction. Analytical methods 6, 1330-1340.
Cramp, L.J.E., Evershed, R.P., 2014. Reconstructing aquatic resource exploitation in human Prehistory using lipid biomarkers and stable isotopes. Treatise on geochemistry: archaeology and anthropology. In: Holland, H.D., Turekian, K.K., (Eds.). Elsevier, Oxford, 319-339.
Constantinescu, B., Cristea-Stan, D., Kovács, I., Szőkefalvi-Nagy, Z., 2014. Provenance studies of Central European Neolithic obsidians using external beam milli-PIXE spectroscopy. Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms 318, 145–148.
Czekaj-Zastawny, A., 2009. Settlement of the Linear Pottery Culture in Southeastern Poland (The First Neolithic Sites in Central/South-East European Transect Volume V = BAR S2049), Oxford.

Czekaj-Zastawny, A., 2014. Brzezie 17. Osada kultury ceramiki wstęgowej rytej. (Via Archaeologica. Źródła z badań wyko- paliskowych na trasie autostrady A4 w Małopolsce). Krakowski Zespół do Badań Autostrad, Kraków.
Czekaj-Zastawny, A., 2017. The first farmers from the South – Linear Pottery culture. In: Włodarczak,P. (Ed.), 5500 – 2000 BC (= The Past Societies. Polish lands from the first evidence of human presence to the Early Middle Ages, vol. 2, P. Urbańczyk Ed.). IAE PAN, Warszawa, pp. 21-62.
Czekaj-Zastawny A., Rauba-Bukowska A. 2014. Technology of the earliest vessels in the upper Vistula River basin — imports against local pottery, [in:] T.L. Kienlin, P. Valde-Nowak, M. Korczyńska, K. Cappenberg, J. Ociepka (eds.), Settlement, Communication and Exchange around the Western Carpathians. International Workshop held at the Institute of Archaeology, Jagiellonian University, Kraków, October 27–28, 2012, Oxford, p. 95–107;
Czekaj-Zastawny A., Kadrow, S., Rauba-Bukowska, A. 2017. Ceramic raw material acquisition and transfer of technological ideas among the Early Neolithic communities around the Western Carpathians. In: Burnez-Lanotte, L. (Ed.), Matières à Penser: Raw materials acquisition and processing in Early Neolithic pottery productions. Matières à penser: sélection et traitement des matières premières dans les productions potières du Néolithique ancien. Proceedings of the Workshop of Namur (Belgium) Actes de la table ronde de Namur (Belgique) 29 et 30 mai 2015 – 29 and 30 May 2015 (= Société. Préhistorique Française 11). Société Préhistorique Française, Paris, pp. 81-91.
Czekaj-Zastawny A., Rauba-Bukowska A., Hreha R., 2018. Colorants used for decoration of the Bükk Culture vessels. In: Valde-Nowak, P., Sobczyk, K., Nowak, M., Źrałka, J. (Eds.), Multas per gentes et multa per saecula. Amici magistro et collegae suo Ioanni Christopho Kozłowski dedicant. Kraków: Jagiellonian University in Kraków, Alter, 351-359.
Czekaj-Zastawny, A., Rauba-Bukowska, A., Kukułka, A., Kufel-Diakowska, B, Lityńska-Zając, M., Moskal-del Hoyo, M., Wilczyński, J., 2020 The earliest farming communities north of the Carpathians: The settlement at Gwoździec site 2. PLoS ONE, 15(1), e0227008.
Czekaj-Zastawny, A., Rauba-Bukowska, A., Kukułka, A., Bochnia, M., 2021. Ceramika naczyniowa kultury ceramiki wstęgowej rytej. In: Czekaj-Zastawny, A., Rauba-Bukowska, A., Kukułka, A. (Eds.), Najstarsza osada kultury ceramiki wstęgowej rytej z terenu Polski Gwoździec stan. 2, gm. Zakliczyn/The earliest settlement of the Linear Pottery Culture from the territory of Poland Gwoździec site 2, com. Zakliczyn. Instytut Archeologii i Etnologii PAN, Muzeum Okręgowe w Tarnowie, Kraków, 63-123.
Daszkiewicz, M., Maritan, L., 2016. Experimental Firing and Re-firing. In: Hunt, A.M.W. (Ed.), The Oxford Handbook of Archaeological ceramic Analysis. Oxford: Oxford University Press, 487-508, Pl. 5-9.
Dębiec, M., 2014. Zwięczyca 3. Eine Bandkeramische Siedlung Am Wisłok. Oficyna Wydawnicza ZIMOWIT, Rzeszów.
Dębiec, M., Saile, T., Alagierski, P., Rauba-Bukowska, A., 2021. Ein Ungar In Polen. Zu Einer Frühneolithischen Statuette Aus Kosina 62 Bei Łańcut Im Südöstlichen Polen. Archäologisches Korrespondenzblatt 51, 23-35.
Elburg, M., Elburg, R., Greig, A., 2002. Obsidian in Sachsen und die Verwendung von ICP-MS zur Herkunftsbestimmung von Rohmaterialien. Arbeits- und Forschungsberichte zur sächsischen Bodendenkmalpflege 44, 391–397.

Evershed, R. P., Heron, C., Goad, L.J., 1990. Analysis of organic residues of archaeological origin by high-temperature gas chromatography and gas chromatography-mass spectrometry. The Analyst 115: 1339-1342.
Fábián, S. 2010. Siedlung Der Zseliz-Periode Der Linearbandkeramik in Szécsény-Ültetés. Antaeus 31–32 (2010) 225–283.
Furholt, M., Cheben, I., Müller, J., Bistáková, A., Wunderlich, M., Müller-Scheessel, N. (Eds.) 2020. Archaeology In The Žitava Valley I. The LBK and Želiezovce settlement site of Vráble (=Scales of Transformation in Prehistoric and Archaic Societies 9). Sidestone Press, Leiden.
Furholt, M., Müller-Scheeßel, N., Wunderlich, M., Cheben, I., Müller, J., 2020. Communality and Discord in an Early Neolithic Settlement Agglomeration: The LBK Site of Vráble, Southwest Slovakia. Cambridge Archaeological Journal 30, 469-489.
Godłowska, M., 1982. Nowohucki zespół osadniczy na tle wpływów południowych we wczesnym i środkowym neolicie Małopolski. Wiadomości Archeologiczne 47, 143-160.
Golański, S. Rzepecki and M. Wąs (eds), Nie tylko krzemienie. Not only flints. Studia ofiarowane prof. Lucynie Domańskiej w 45-lecie pracy naukowo-dydaktycznej i w 70. rocznicę urodzin. Łódź: Instytut Archeologii Uniwersytetu Łódzkiego; Łódzka Fundacja Badań Naukowych; Stowarzyszenie Naukowe Archeologów Polskich Oddział w Łodzi, 237-247.
Wilczyński J. 2018. Chipped stone inventories of the malice culture from southern Poland, In: Valde-Nowak, P., Sobczyk, K., Nowak, M., Źrałka, J. (eds), "Multas per gentes et multa per saecula", Kraków, pp. 451-458.
Govindaraju, K., 1994. Compilation of working values and sample description for 383 geostandards. Geostandards Newsletter, Special Issue XVIII, 1-158.
Hammann, S., Cramp, L. J. E., Whittle, M., Evershed, R.P. 2018. Cholesterol degradation in archaeological pottery mediated by fired clay and fatty acid pro-oxidants. Tetrahedron Letters 59(50), 4401-4404.
Hughes, R.E., 1998. On reliability, validity, and scale in obsidian sourcing research. In: Ramenofsky, A.F., Steffen, A. (Eds.), Unit Issues in Archaeology: Measuring Time, Space, and Material. University of Utah Press, Salt Lake City, pp. 103–114.
Hughes, R.E., 2010. Determining the geologic provenance of tiny obsidian flakes in archaeology using nondestructive EDXRF. American Laboratory 42 (7), 27-31.
Hughes, R.E., Werra, D.H., 2014. The source of Late Mesolithic obsidian recovered from Rydno XIII/1959, Central Poland. Archeologia Polski 59(1-2), 31–46.
Hughes, R.E., Werra, D.H., Sulgostowska, Z. 2018. On the Sources and Uses of Obsidian During the Paleolithic and Mesolithic in Poland. Quaternary International 468, 84-100.
Kabaciński, J., Sobkowiak-Tabaka, I., Kasztovszky, Z., Pietrzak, S., Langer, J.J., Biró, K.T., Maróti, B. 2015. Transcarpathian influences in the Early Neolithic of Poland. A case study of Kowalewko and Rudna Wielka sites. Acta Archaeologica Carpathica 50, 5–32.
Kaczanowska, M., Godłowska, M. 2009. Contacts between the Eastern and Western Linear Cultures in South-Eastern Poland.In: Kozłowski, J.K. (Ed.), Interactions between different models of Neolithization North of the Central European Agro-Ecological Barrier.Polska Akademia Umiejętności,Kraków, pp. 137-150.
Kaczanowska, M., Kozłowski, J.K., Zakościelna, A., 1987.Chipped Stone Industries of the Linear Band Pottery Culture Setllements in the Nowa Huta Region. Przegląd Archeologiczny 34, 93-132.

Kadrow, S., 1990. Osada neolityczna na stan. nr 16 w Rzeszowie na Osiedlu Piastów. Sprawozdania Archeologiczne 41, 9-76.
Kadrow, S., 2020. Faza i styl żeliezowski kultury ceramiki wstęgowej rytej w Polsce południowowschodniej. In: Dębiec, M., Saile, T. (Eds.), A planitiebus usque ad montes. Studia archaeologica Andreae Pelisiak vitae anno sexagesimo. Rzeszów, pp. 143-152.
Kadrow, S., Rauba-Bukowska, A., 2016. Ceramics Technology and Transfer of Ideas in the West Carpathian Region in Neolithic. In: Ţerna, S., Govedarica, B. (Eds.), Interactions, Changes and Meanings. Essays in honour of Igor Manzura on the occasion of his 60th birthday. University of High Anthropological School, Kishinev, pp. 65-72.
Kadrow, S., Rauba-Bukowska, A., 2017. The selection of ceramic raw material: convenience or a technologicalidea? A case study of the Danubian cultures north of the Carpathians. Archeologické rozhledy 69, 261-280.
Kaminská L'. 2018. Use of obsidian from the Paleolithic to the Bronze Age in Slovakia. Archeometriai Műhely 15(3), 197-212.
Kapcia M., Moskal-del Hoyo M., Korczyńska-Cappenberg M., Wacnik A., Kenig R., Nowak M. 2023. Early Neolithic plant remains from the Carpathian foothill zone (southern Poland): a case study of the Biskupice site no. 18. In: Engelbogen, F., Taylor, N., Ricci A. (Ed.), Abstract Book Kiel Conference. Scales of Social, Environmental & Cultural Change in Past Societies. Kiel University, March 13–18, 2023. Abstract book: 58. doi.org/10.38071/2023-00120-3
Keeney, M., Katz, I. and Allison, M.J., 1962. On the probable origin of some milk fat acids in rumen microbial lipids. Journal of the American Oil Chemists' Society 39(4), 198-201.
Kerig, T., Hilpert, J., Strohm, S., Berger, D., Denis, S., Gauthier, E., Gibaja, J.F., Mallet N., Massa M., Mazzucco N., Nessel B., Pelegrin J., Pétrequin P., Sabatini S., Schumacher T.X., Serbe B.and Wilkinson, T. (2023). Interlinking research: The Big Exchange project. Antiquity, 97(394), E22. doi:10.15184/aqy.2023.78
Kondracki, J., 1998. Geografia regionalna Polski. Polskie Wydawnictwo Naukowe, Warszawa.
Korczyńska, M., Kenig, R., Nowak, M., Czekaj-Zastawny, A., Nowak, M., Moskal-del Hoyo, M., 2021 Linear Pottery culture face vessel from the site Biskupice 18, southern Poland. Sprawozdania Archeologiczne 73/1, 155-186.
Kozłowski J.K. 1968. Materiały neolityczne i eneolityczne odkryte na stanowisku Nowa Huta-Wyciąże I (badania w latach 1950-1952). Materiały Archeologiczne Nowej Huty 1, 13-90.
Kozłowski J.K. 2006. Grupa Wyciąże-Złotniki i bezpośrednie oddziaływania polgarskie. In: Kaczanowska, M. (Ed.), Dziedzictwo cywilizacji naddunajskich: Małopolska na przełomie epoki kamienia i miedzi. Kraków: Muzeum Archeologiczne w Krakowie, 53-61.
Kozłowski, J.K., Kaczanowska, M., Czekaj-Zastawny, A., Rauba-Bukowska, A., Bukowski, K., 2014. Early/Middle Neolithic Western (LBK) vs Eastern (ALPC) Linear Pottery Cultures: Ceramics and Lithic Raw Materials Circulation. Acta Archaeologica Carpathica 49, 37-76.
Kuzm, I., 1990. Plastika Želiezovskej skupiny z Mužle-Čenkova. Slovenská Arch. 38/2, 429-452.
Lech, J., 1989. A Danubian raw material exchange network: a case study from Bylany. In: Rulf, J. (Ed.), Bylany Seminar 1987: Collected papers. Praha: Archeologický ústav CSAV, 111-120.
Lech, J., 2012. The late Neolithic flint and stone industries. In: Longworth, I., Varndell, G., Lech, J. (Eds.), Excavations at Grimes Graves Norfolk 1972–1976. Fascicule 6. Excavation and

Exploration beyond the Deep Mines. British Museum Press for the Trustees of the British Museum, London, pp. 90–144.
Matlova, V., Roffet-Salque, M., Pavlu, I., Kyselka, J., Sedlarova, I., Filip, V., Evershed, R.P., 2017. Defining pottery use and animal management at the Neolithic site of Bylany (Czech Republic). Journal of Archaeological Science: Reports 14, 262-274.
Moskal-del Hoyo, M., Korczyńska-Cappenberg M., Kenig R., 2022 (unpublished). Raport z weryfikacyjnej prospekcji powierzchniowej, przeprowadzonej w Biskupicach na obszarze AZP 104-58, unpublished manuscript. Wojewódzki Urząd Ochrony Zabytków w Krakowie.
Moskal-del Hoyo, M., Rauba-Bukowska, A., Lityńska-Zając, M., Mueller- Bieniek, A., Czekaj-Zastawny, A., 2017. Plant materials used as temper in the oldest Neolithic pottery from south-eastern Poland. Vegetation History and Archaeobotany 26, 329-344.
Nowak, M., Moskal-del Hoyo, M., Mueller-Bieniek, A., Lityńska- Zając, M., Kotynia, K., 2017. Benefits and weaknesses of radiocarbon dating of plant material as reflected by Neolithic archaeological sites from Poland, Slovakia and Hungary. Geochronometria 44, 188–201.
Oberc, T., Czekaj-Zastawny, A., Rauba-Bukowska, A., 2022. Radiocarbon dating for the Linear Pottery Culture from the territory of Poland – research problems. In: Grygiel, M., Obst, P. (Eds.), Walking Among Ancient Trees. Studies in honour of Ryszard Grygiel and Peter Bogucki on the 45th anniversary of their research collaboration. Fundacja Badań Archeologicznych Imienia Profesora Konrada Jażdżewskiego. Muzeum Archeologiczne i Etnograficzne w Łodzi, Łódź, pp. 184-212.
Pavúk, J., 1969. Chronologie der Želiezovce-Gruppe. Slovenská Archeológia 17, 269-367.
Pavúk, J., 1994. Štúrovo. Ein Siedlungsplatz der Kultur mit Linerakeramik und der Želiezovce-Gruppe. Nitra.
Pelisiak, 2018. Centrum i peryferia osadnictwa w neolicie i wczesnej epoce brązu na wschodnim Podkarpaciu i we wschodniej części polskich Karpat [Core and Peripheries of the Neolithic and Early Bronze Age Settlements on the Eastern Carpathian Forelands
and the Eastern Part of Polish Carpathians]. Wydawnictwo Uniwersytetu Rzeszowskiego. Rzeszów.
Polskie Towarzystwo Gleboznawcze, 2009. Klasyfikacja uziarnienia gleb i utworów mineralnych PTG 2008. Roczniki Gleboznawcze 60/2, 5-16.
Pyzel J. 2009. Migration und Kontakte in der Bandkeramik Kujawiens. In: Krenn-Leeb, A., Beier, H.-J., Claßen, E., Falkensten, F., Schwenzer, S. (Eds), Varia Neolithica 5. Mobilität, Migration und Kommunikation in Europa während des Neolithikums und der Bronzezeit. Beiträge der Sitzungen der Arbeitsgemeinschaften Neolithikum und Bronzeit während der Jahrestagung des West- und Süddeutschen Verbandes für Altertumsforschung e. V. in Xanten, 6.-8- Juni 2006 (= Beiträge zur Ur- und Frühgeschichte Mitteleuropas 53). Langenweißbach: Beier & Beran Archäologische Fachliteratur, 49-52.
Quinn, P.S., 2013. Ceramic Petrography. The Interpretation of Archaeological Pottery and Related Artefacts in Thin Section. Archaeopress, Oxford.
Rauba-Bukowska A. 2014a. Wyniki badań mineralogiczno-petrograficznych naczyń kultury ceramiki wstęgowej rytej ze stanowiska Brzezie 17 gm. Kłaj. In: Czekaj-Zastawny, A., Brzezie 17. Osada kultury ceramiki wstęgowej rytej (= Via Archaeologica. Źródła z badań wykopaliskowych na trasie autostrady A4 w Małopolsce). Kraków: Krakowski Zespół do Badań Autostrad,437-458.

Rauba-Bukowska A. 2014b. Wyniki badań mineralogiczno-petrograficznych naczyń importowanych kręgu wschodniolinearnego, odkrytych na stanowisku Brzezie 17, gm. Kłaj. In: Czekaj-Zastawny, A., Brzezie 17. Osada kultury ceramiki wstęgowej rytej (= Via Archaeologica. Źródła z badań wykopaliskowych na trasie autostrady A4 w Małopolsce). Kraków: Krakowski Zespół do Badań Autostrad, 459-468.
Rauba-Bukowska, A., 2019. The diversity of ceramic raw materials used in the production of Neolithic vessels in the upper Vistula basin near Krakow. Analecta Archaeologica Ressoviensia 14, 11-20.
Rauba-Bukowska, A., 2021.Technological indicators in the pottery production of the late Linear Pottery culture and the Malice culture. Sprawozdania Archeologiczne 73-1, 119-151.
Rauba-Bukowska, A, Czekaj-Zastawny, A., 2020. Changes in the pottery production of the Linear Pottery Culture – origins and directions of ideas. In: Spataro,M., Furholt, M. (Eds.), Detecting and explaining technological innovation in prehistory (= Scales of Transformation 7). Sidestone Press, Leiden, pp. 73-83.
Rauba-Bukowska, A., Czekaj-Zastawny, A., Grabowska, B., Zastawny, A., 2007. Wyniki badań mineralogiczno-petrograficznych naczyń kultury ceramiki wstęgowej rytej i malickiej ze stanowisk Brzezie 17 i Targowisko 11, gm. Kłaj, woj. Małopolskie, Results of mineralogical and petrographic research on vessels of linear band pottery culture and malice culture from sites Brzezie 17 and Targowisko 11, Kłaj commune, małopolska province. Sprawozdania Archeologiczne 59, 63-113.
Reedy, Ch.L., 2008. Thin-Section Petrography of Stone and Ceramic Materials. London: Archetype Publications.
Reimer, P.J., Bard, E., Bayliss, A., Beck, J.W., Blackwell, P.G., Ramsey, C.B., Buck, C.E., Cheng, H., Edwards, R.L., Friedrich, M., Grootes, P.M., Guilderson, T.P., Haflidason, H., Hajdas, I., Hatté, C., Heaton, T.J., Hoffmann, D.L., Hogg, A.G., Hughen, K.A., Kaiser, K.F., Kromer, B., Manning, S.W., Niu, M., Reimer, R.W., Richards, D.A., Scott, E.M., Southon, J.R., Staff, R.A., Turney, C.S.M., van der Plicht, J., 2013. IntCal13 and Marine13 radiocarbon age calibration curves 0–50,000 years cal BP. Radiocarbon 55, 1869–1887.
Renfrew, C. M. (1975). Trade as action at a distance, questions of integration and communication. In Sabloff, J. A., and Lamberg-Karlovsky, C. C. (eds.), Ancient Civilization and Trade, University of New Mexico Press, Albuquerque, pp. 3–59.
Riebe, D.J., 2019. Sourcing Obsidian from Late Neolithic Sites on the Great Hungarian Plain: Preliminary p-XRF Compositional Results and the Socio-Cultural Implications. Interdisciplinaria Archaeologica 10, 113–120.
Roffet-Salque, M., Banecki, B., Krüger, M., Pyzel, J., Smyth, J., Evershed, R.P., 2019. Chronologiczne i przestrzenne trendy użytkowania ceramiki w świetle analiz pozostałości tłuszczów w naczyniach KCWR / Chronological and spatial trends in pottery use revealed through lipid residue analyses of LBK pottery vessels.In: Pyzel, J. (Ed.), Ludwinowo, stanowisko 7. Osada neolityczna na Kujawach. Wydawnictwo i pracownia archeologiczna Profil-Archeo/Wydawnictwo Uniwersytetu Gdańskiego, Pękowice-Gdańsk, pp. 301-316.
Robson, H.K., England, F., Lucquin, A., Craig, O.E., 2021. Analiza pozostałości organicznych w ceramice (ORA – Organic Resiude Analysis). In: Czekaj-Zastawny, A., Rauba-Bukowska, A., Kukułka, A. (Eds.), Najstarsza osada kultury ceramiki wstęgowej rytej z terenu Polski Gwoździec stan. 2, gm. Zakliczyn/The earliest settlement of the Linear Pottery Culture from

the territory of Poland Gwoździec site 2, com. Zakliczyn. Instytut Archeologii i Etnologii PAN, Muzeum Okręgowe w Tarnowie, Kraków, pp. 132-141.
Rosania, C.N., Biró K.T., Ryzhov S., Trnka, G., Glascock, M.D., 2008. Revisiting Carpathian Obsidian. Antiquity Project Gallery 82.
Saile, T., Dębiec, M., Buzea, D., 2022. Aspects of a Bandkeramik settlement near Olteni in Transylvania. Praehistorische Zeitschrift 97(1), 1–21.
Salque, M., Grygiel, R., Szmyt, M., 2013. Earliest evidence for cheese making in the sixth millennium BC in northern Euro-pe. Nature 493, 522–525.
Sudoł-Procyk, M., Brandl, M., Krajcarz, M., Malak, M., Skrzatek, M., Stefański, D., Trela-Kieferling, E., Werra, D. H. 2021. Chocolate flint: New perspectives on its deposits, mining, use and distribution by prehistoric communities in Central Europe. Antiquity 95(383), e25.
Szeliga, M., 2009. Znaczenie obsydianu karpackiego w gospodarce surowcowej najstarszych społeczności rolniczych na ziemiach polskich. In: Gancarski, J. (Ed.), Surowce Naturalne w Karpatach Oraz Ich Wykorzystanie w Pradziejach i Wczesnym Średniowieczu. Krosno, pp. 287–324.
Szeliga, M., 2018. Osadnictwo kultury ceramiki wstęgowej rytej. In: Niezabitowska-Wiśniewska, B., (Ed.), Puławy-Włostowice. Wielokulturowe stanowisko z zachodniej Lubelszczyzny / Puławy-Włostowice. Multicultural site in the western Lublin region. Instytut Archeologii Marii Curie-Skłodowskiej w Lublinie, Lublin, pp. 176-221.
Szeliga M. 2021. The inflow of obsidian north of the Carpathians during the Neolithic - chrono-cultural variability of distribution. In: Biró, K.T., Markó, A. (Eds), Beyond the Glass Mountains. Papers Presented for the 2019 International Obsidian Conference 27-29 May 2019, Sárospatak (= Inventaria Praehistorica Hungariae 14). Budapest: Magyar Nemzeti Múzeum, 69-94.
Szeliga, M., Kasztovszky, Z., Szilágyi, V., 2019. New PGAA data on the origin of Early Neolithic (LPC) obsidian in the upper Vistula Basin. In: Markó, A., Szilágyi, K., Biró, K.T. (Eds.), International Obsidian Conference 2019 27–29 May 2019, Sárospatak (Hungary), Program, Abstracts, Field Guide. Hungarian National Museum, Budapest, pp.63.
Valde-Nowak, P., 2014. Long Houses on Hilltop – Camps in the Mountains: Some Aspects of the Neolithic in the Dunajec Project. In: Kienlin, T.L., Valde-Nowak, P., Korczyńska, M., Cappenberg, K., Ociepka, J. (Eds.), Settlement, Communication and Exchange around the Western Carpathians.International Workshop at the Institute of Archaeology, Jagiellonian University in Kraków October 27–28, 2012. Archaeopress Archaeology, Oxford, pp. 27-49.
Valde-Nowak, P., 2009. Early farming adaptation in the Wiśnicz Foothills in the Carpathians. Settlements at Łoniowa and Żerków. Recherches Archéologiques 1: 15–35.
Werra, D.H., Hughes, R.E., Nowak, M., Vizdal, M., Gačková, L., 2021. Obsidian Source Use within the Alföld Linear Pottery culture in Slovakia. Sprawozdania Archeologiczne, 73(1), 331–369.
Werra, D.H., Sobkowiak-Tabaka, I. 2017. Elementy kultury bukowogórskiej na Nizinie Polskiej – aspekt teoretyczny. In A. Marciniak-Kajzer, A. Andrzejewski, Aleksander, A., Golański, A., Rzepecki, S., Wąs, M. (Eds), Nie tylko krzemienie/Not only flints. Studia ofiarowane prof. Lucynie Domańskiej w 45-lecie pracy naukowo-dydaktycznej i w 70. Rocznicę urodzin. Łódź, pp. 237–247.

Whelton, H.L., Hammann, S., Cramp, L.J.E., Dunne, J., Roffet-Salque, M., Evershed, R.P., 2021. A call for caution in the analysis of lipids and other small biomolecules from archaeological contexts. Journal of Archaeological Science 132, 105397.

Whitbread, I.K., 2017.Fabric Description of Archaeological Ceramics. In: Hunt, A.M.W. (Ed.), The Oxford Handbook of Archaeological Ceramic Analysis. Oxford University Press, Oxford, pp. 200-216.

Wilczyński, J., 2014. Neolityczny inwentarz krzemienny oraz obsydianowy z wielokulturowego stanowiska Brzezie 17. In: Czekaj-Zastawny, A., (Ed.), Brzezie 17. Osada kultury ceramiki wstęgowej rytej (Via Archaeologica. Źródła z badań wykopaliskowych na trasie autostrady A4 w Małopolsce). Krakowski Zespół do Badań Autostrad, Kraków, pp. 499-546.

Wilczyński, J., 2016. Flint, Obsidian, and Radiolarite in Lithic Inventories of the LBK culture in Lesser Poland. In: Amkreutz, L., Haack, F., Hofmann, D., van Wijk, I. (Eds.), Something out of the Ordinary?: Interpreting Diversity in the Early Neolithic Linearbandkeramik and Beyond. Newcastle upon Tyne: Cambridge Scholars Publishing, 123-139.

Wilczyński, J., Kufel-Diakowska, B., 2021. Wyroby kamienne. In: Czekaj-Zastawny, A., Rauba-Bukowska, A., Kukułka, A. (Eds.), Najstarsza osada kultury ceramiki wstęgowej rytej z terenu Polski. Gwoździec stan. 2, gm. Zakliczyn [The earliest settlement of the Linear Pottery Culture from the territory of Poland. Gwoździec site 2, com. Zakliczyn], Kraków: IAE PAN, Muzeum Okręgowe w Tarnowie, pp. 142-215.

Captions:

Fig. 1. Location of the site 18 in Biskupice against the background of the LBK settlement in western Lesser Poland (Czekaj-Zastawny 2014, fig. 57).

Fig. 2. Plan of the archaeological excavations at Biskupice site 18. Remnants of at least four houses were discovered (black rectangles). Photo: M. Korczyńska-Cappenberg.

Fig. 3. Location of pit no. 25 within house no. 2 at Biskupice site 18, in which the face vessel was found. Photos: M. Korczyńska-Cappenberg and A. Walanus. For scales: see fig. 2 and 5 a.

Fig. 4. A share of pottery, flint and obsidian finds from house no. 2 of Biskupice site 18. For details: see Table S1.

Fig. 5. Calibrated ranges for the samples taken from house no. 2 of Biskupice site 18. For details: see Table 1.

Fig. 6. Bayesian modelling of calibrated dates for the samples taken from house no. 2 at Biskupice site 18.

Fig. 7. Selected pottery from house no. 2 from Biskupice site 18. Drawings: M. Korczyńska-Cappendberg (a) and R. Kenig (b-h).

Fig. 8. Examples of pottery sherds and ceramic fabrics of the technological groups from house no. 2 at Biskupice site 18. Photos: R. Kenig (pottery sherds) and A. Rauba-Bukowska (thin-sections). For details: see Tables 5 and 6.

Fig. 9. Results of the lipid residue analysis from house no. 2 from Biskupice site 18. A) Partial gas chromatogram of a typical lipid extract interpreted as animal fat (BIS7498). Peak identities are: FA n and FA n:i, fatty acids containing n carbon atoms and i double bonds (detected as fatty acid methyl esters); IS, internal standard (*n*-tetratriacontane); b) $\delta^{13}C$ values for the $C_{16:0}$ and $C_{18:0}$ fatty acids prepared from lipid extracts from open bowls (open circles) and spherical bowls (filled circles). The three fields correspond to the P = 0.684 confidence ellipses for animals raised on a strict C_3 diet in Britain (Copley et al., 2003); c) A scheme showing a relationship between types of the vessels and concentration of lipids.

Fig. 10. Kernel density analysis of flint (a) and obsidian (b) artefacts from house no. 2 at Biskupice site 18.

Fig. 11. Selected obsidian artifacts from house no. 2 at Biskupice site 18 see Table S5. Photos: D. Werra; Drawings: E. Gumińska.

Fig. 12. Results of the XRF analysis of obsidian artefacts from house no. 2 at Biskupice site 18: a) Sr vs. Zr composition of large obsidian artifacts. Symbols plot the artifacts listed in Table S6; b) Normalized Rb/Sr/Zr composition of small obsidian artifacts. Symbols plot the artifacts listed in Table S7. Dashed lines depict the range of composition variation measured in archaeologically significant geological reference samples (adapted from Hughes and Werra, 2014: fig. 4 and 5).

Fig. 13. Directions of Transcarpathian influences to the LBK settlement at Biskupice site 18.

Table 1. Results of the radiocarbon dating of samples taken from house no. 2 from Biskupice site 18.

Table 2. Percentage number of samples assigned to each fabric type at Biskupice site 18 and during all phases of LBK sites from the territory of Lesser Poland (*n* = 302). Technological groups after Rauba-Bukowska and Czekaj-Zastawny, 2020.

Supplementary material

Table S1. Pottery, flint and obsidian finds from house no. 2 of Biskupice site.

Table S2. Results of the petrographic analysis of the pottery sherds from house no. 2 from Biskupice site 18.

Table S3. Results of the petrographic analysis of the pottery sherds from house no. 2 from Biskupice site 18; red - reducing firing; redox - reducing firing with small inflow of air; ox - oxidizing firing.

Table S4. Results of lipid residues analysis: Potsherd sample details and results for sherds from house no. 2 from Biskupice site 18.

Table S5. Technological and morphological description of obsidian artefacts from house no. 2 at Biskupice site 18.

Table S6. EDXRF Composition Estimates for Large Obsidian Artefacts from house no. 2 at Biskupice site 18.

Table S7. Integrated Net Peak Intensity Data for Small Obsidian Artefacts from house no. 2 at Biskupice site 18.

Figure 1

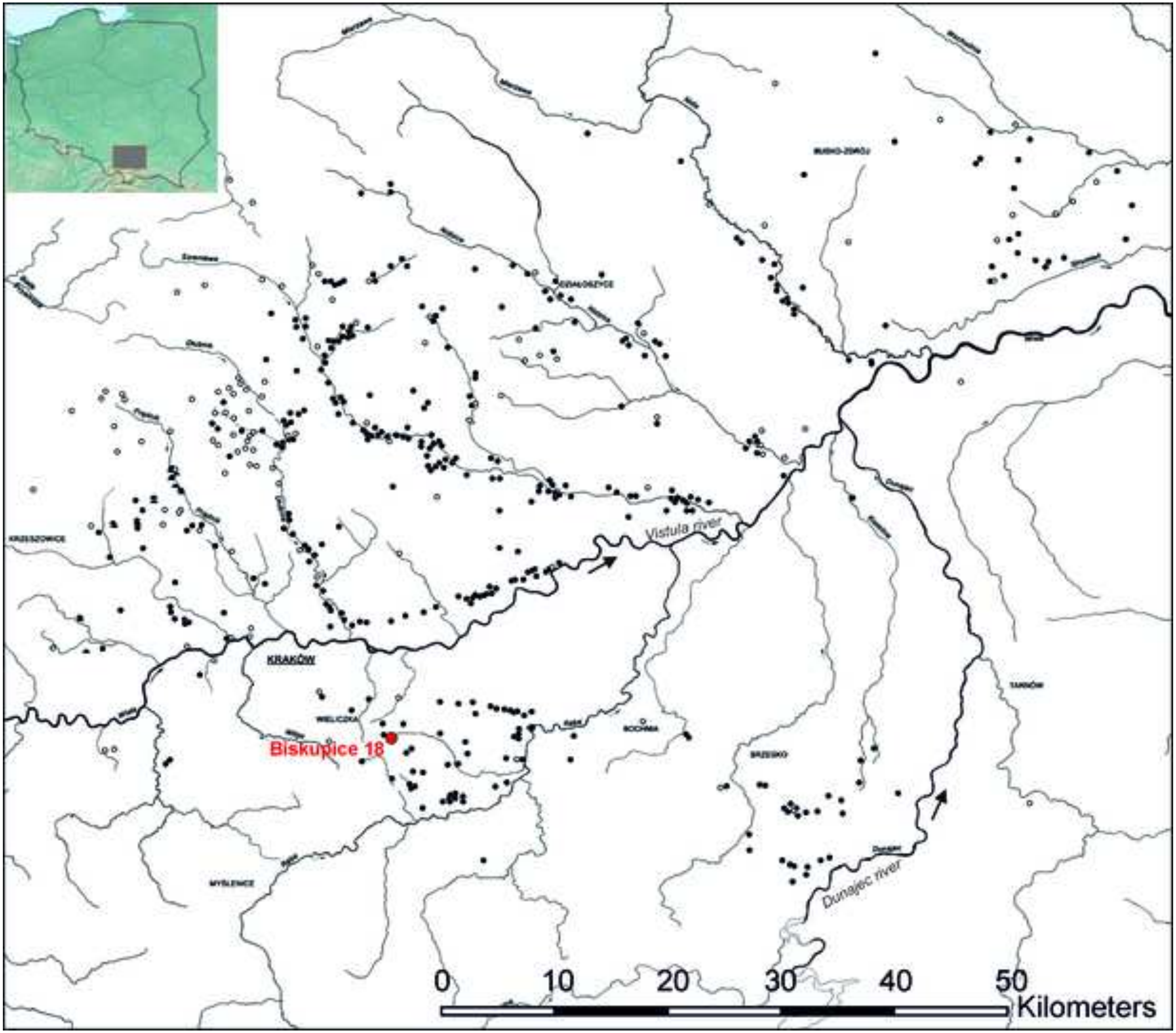
KRAKÓW
Vistula river
Dunajec river
Biskupice 18
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Figure 2

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Figure 3

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Figure 4

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Figure 5

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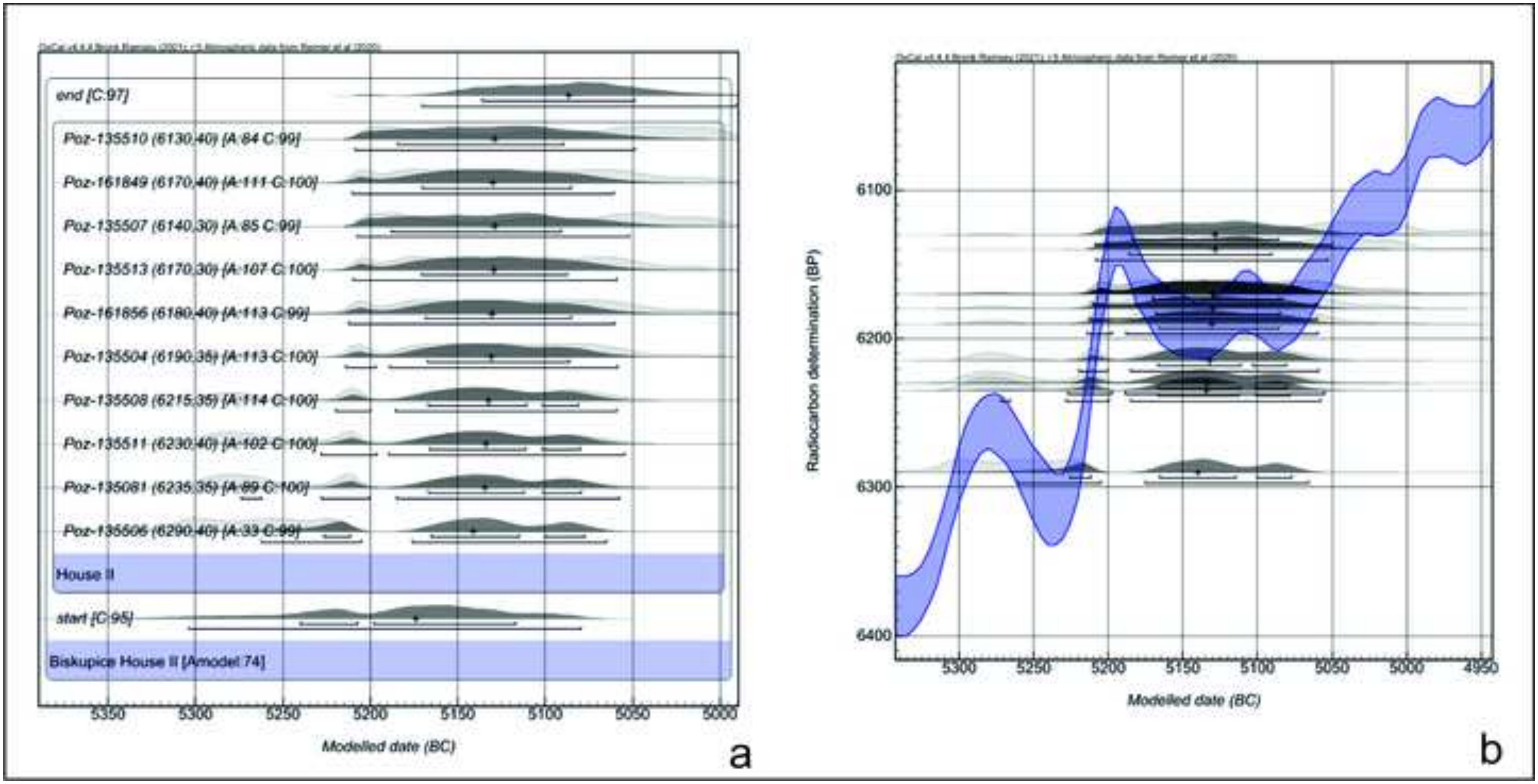

Figure 6

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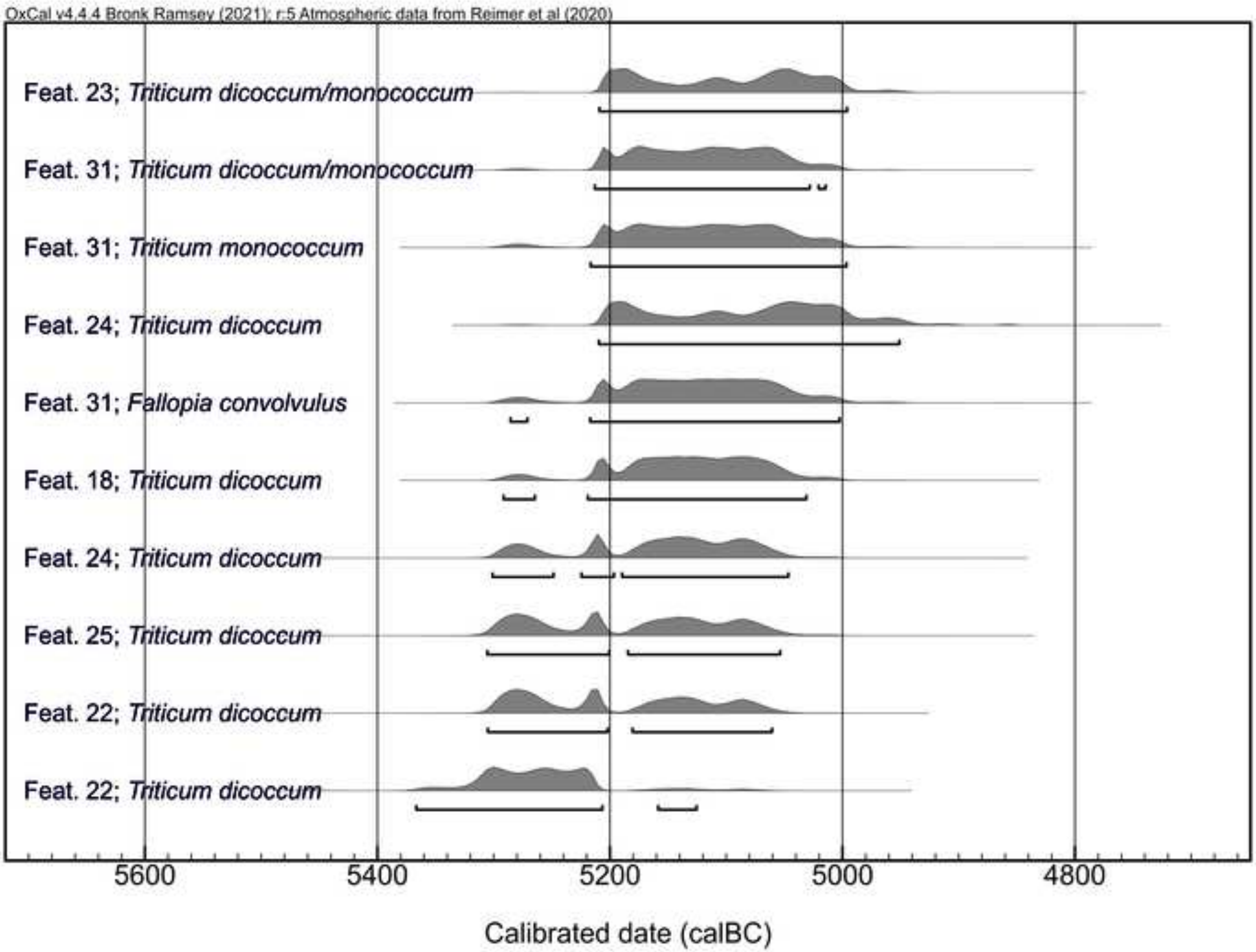

Figure 7

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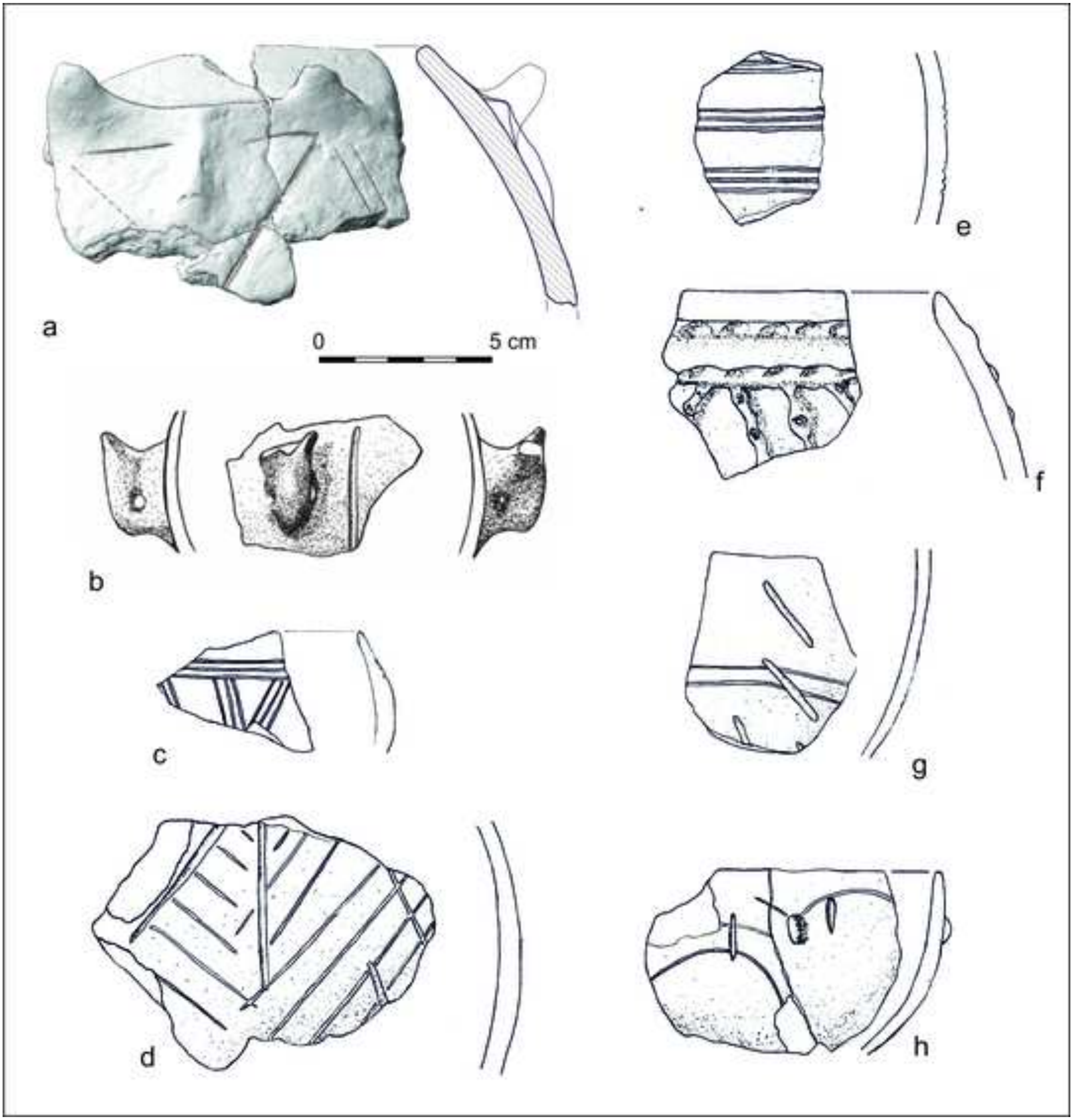

Figure 8

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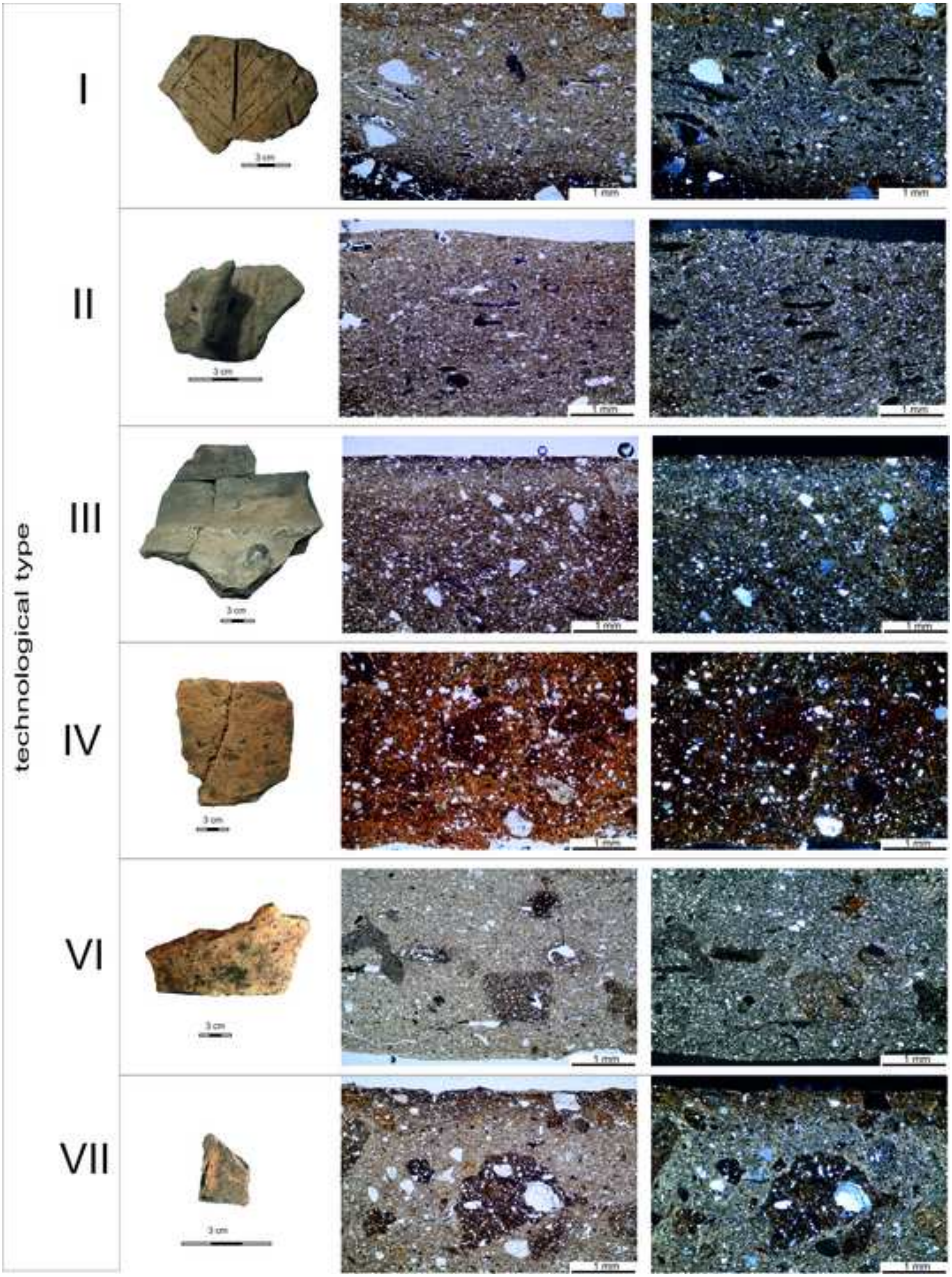

Figure 9

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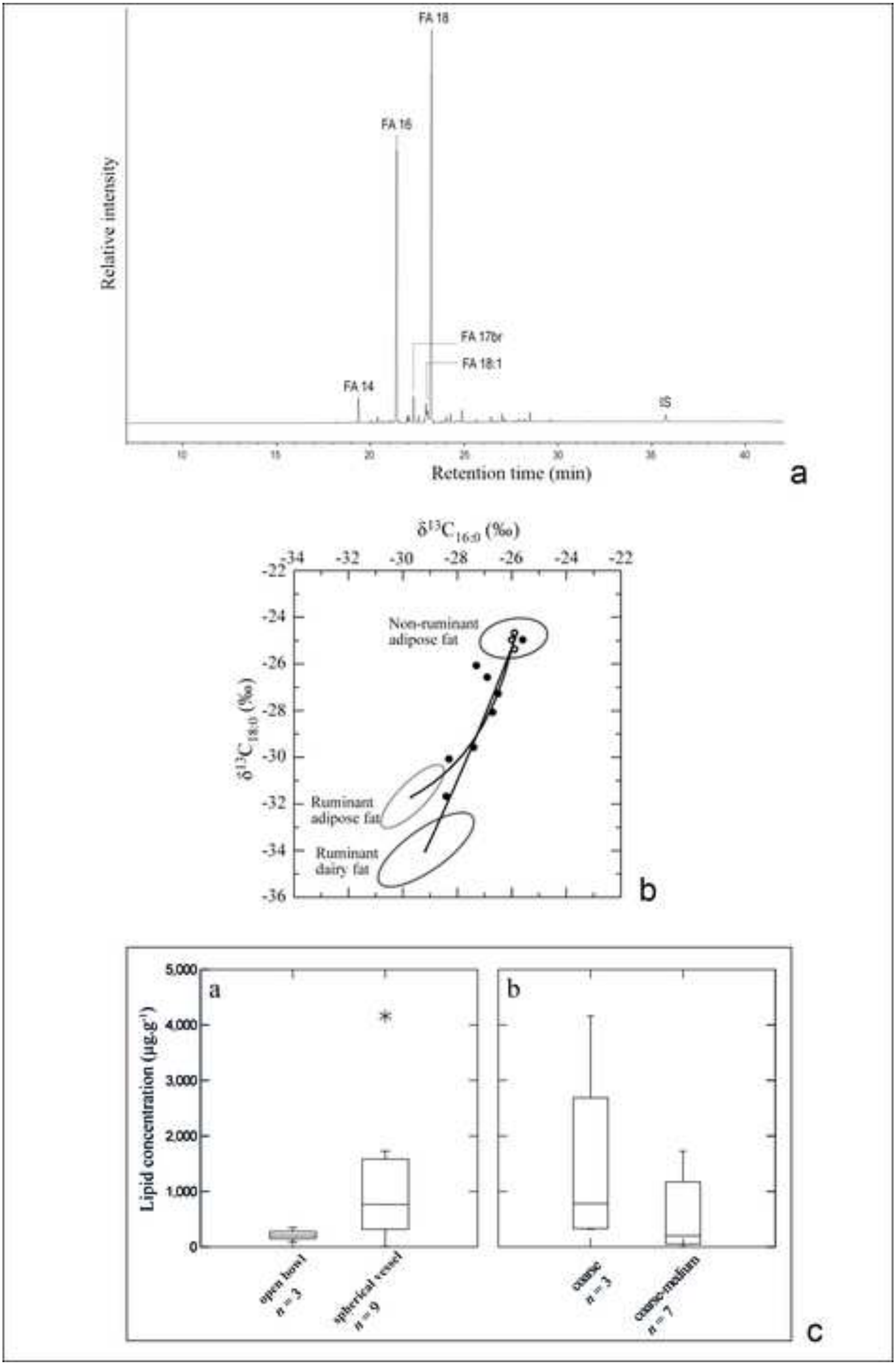

Figure 10

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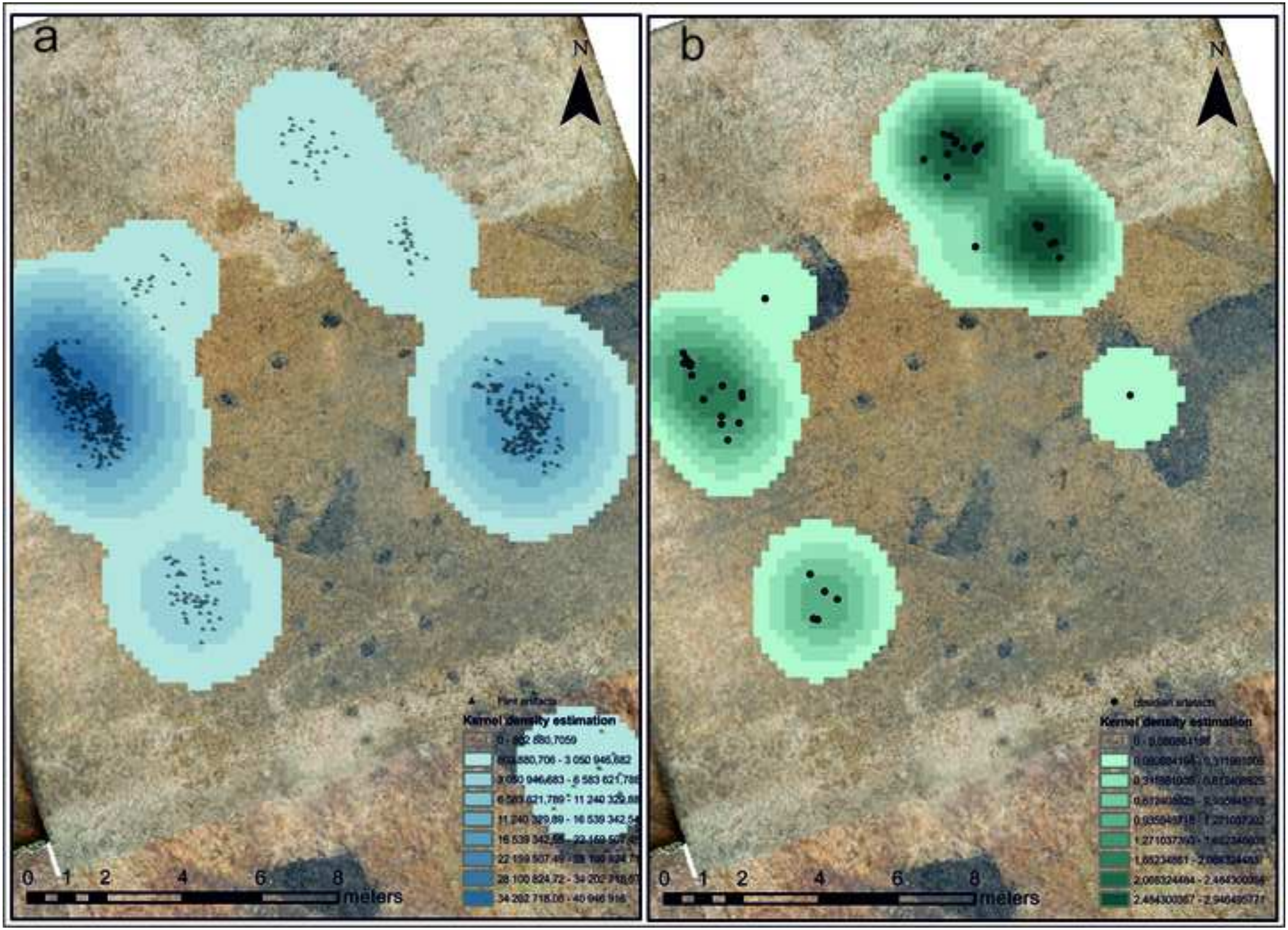

Figure 11

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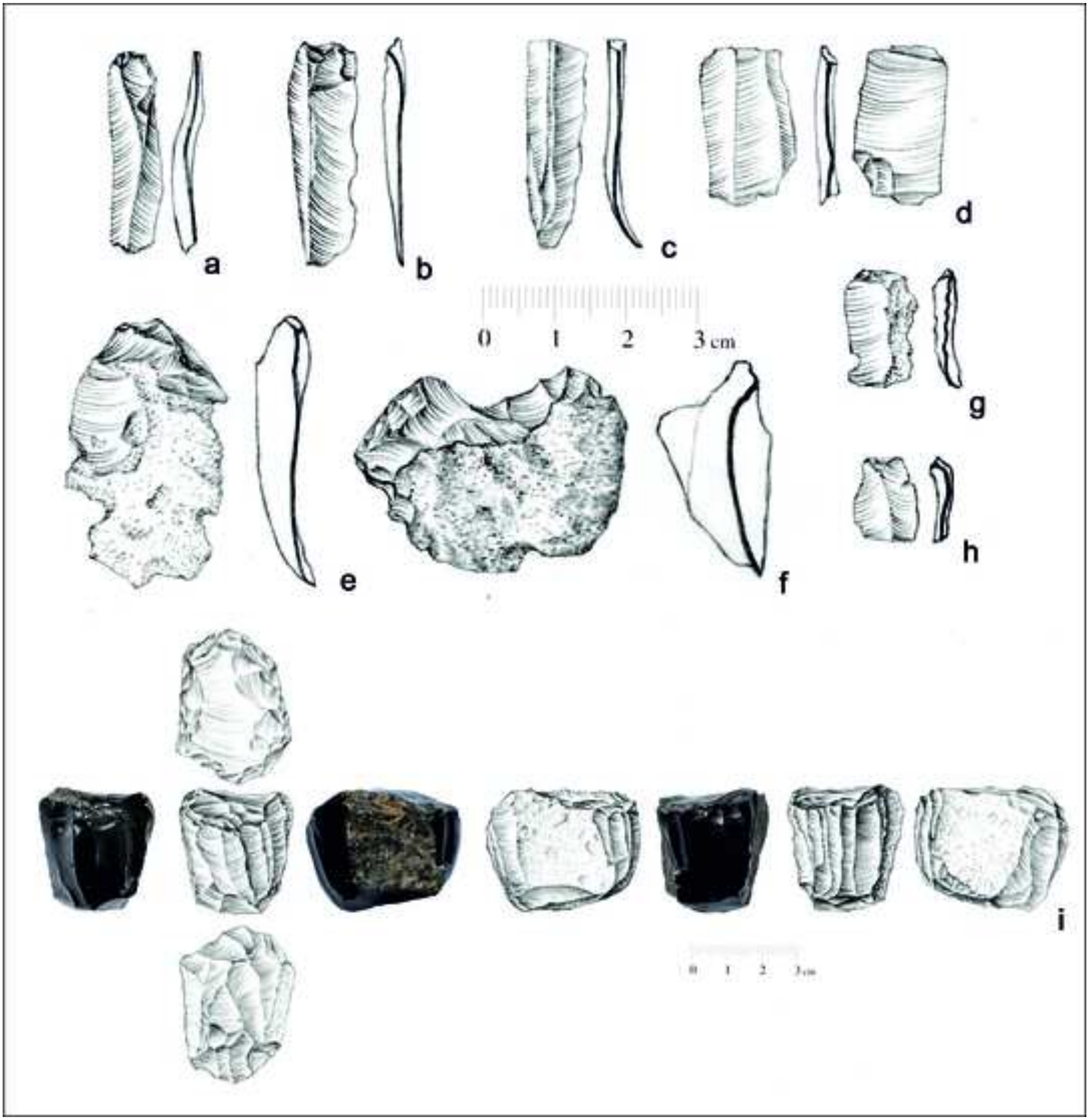

Figure 12

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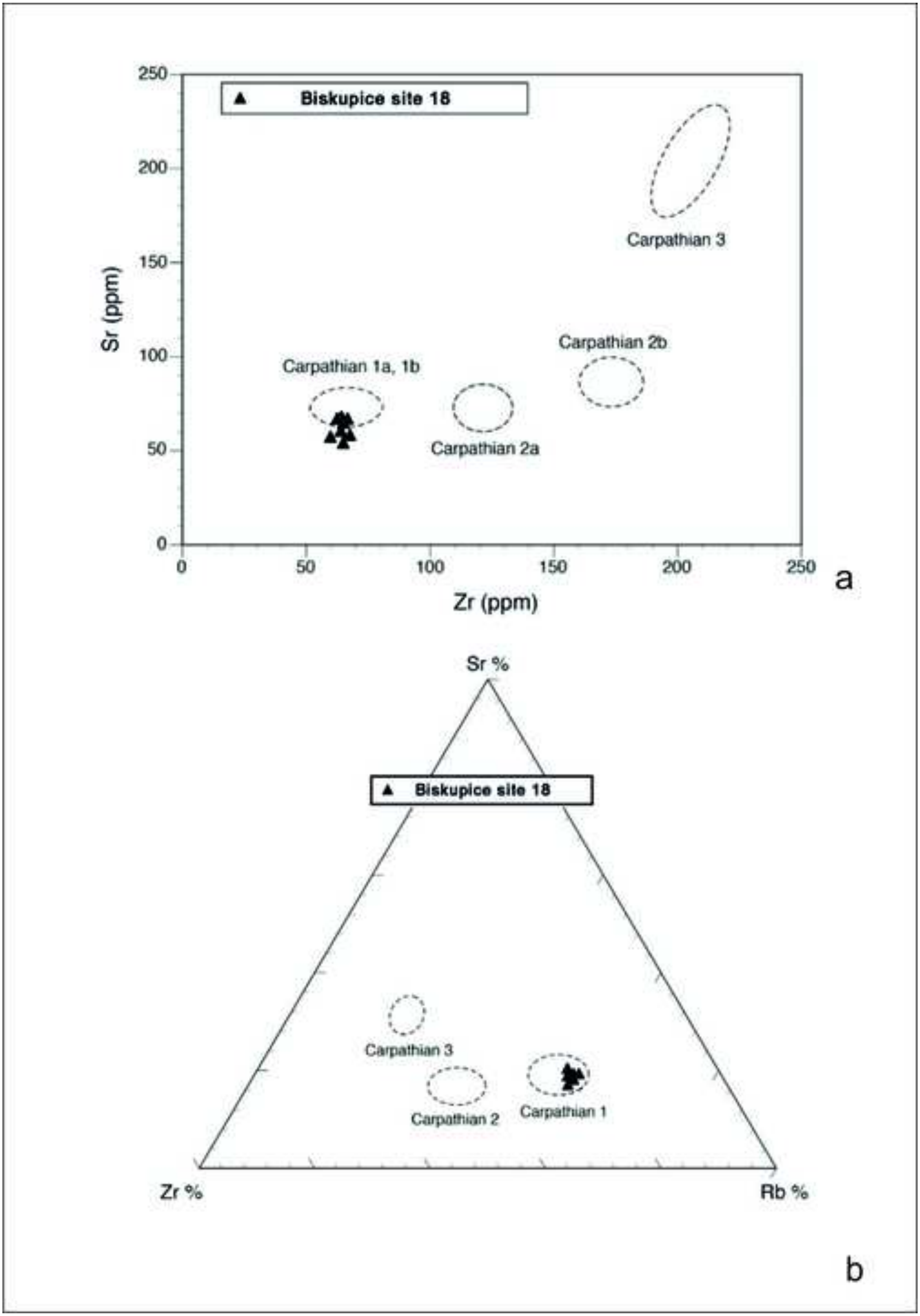

Figure 13

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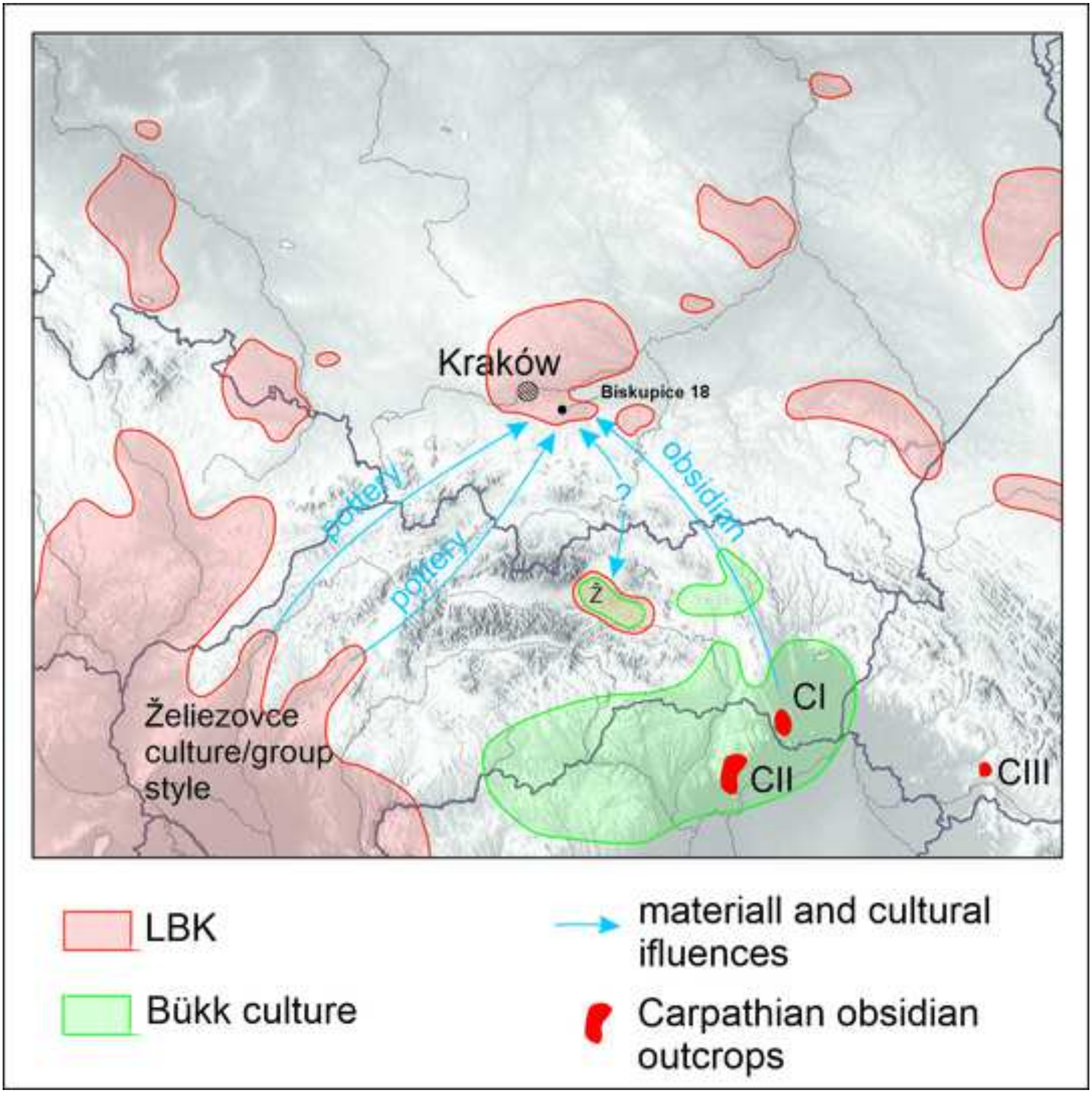

Table 1

No. of Lab	Data BP	SD	68.3% probability	95.4% probability	Feature	No. of sample	Plant species	Remarks
Poz-135507	6140	30	5206BC (22.8%) 5170BC 5115BC (5.9%) 5101BC 5074BC (39.5%) 5005BC	5210BC (95.4%) 4997BC	23	744	*Triticum dicoccum/monococcum*	50-60 cm, elongated pit (charcoal accumulation)
Poz-135513	6170	30	5208BC (3.3%) 5202BC 5185BC (21.3%) 5146BC 5131BC (43.7%) 5054BC	5214BC (94.5%) 5029BC 5021BC (0.9%) 5015BC	31	641	*Triticum dicoccum/monococcum*	40-50 cm, post-hole
Poz-161849	6170	40	5208BC (3.3%) 5201BC 5185BC (22.4%) 5141BC 5136BC (42.6%) 5054BC	5217BC (95.4%) 4997BC	31	803	*Triticum monococcum*	40-60 cm, post-hole
Poz-135510	6130	40	5207BC (19.9%) 5168BC 5117BC (6.5%) 5099BC 5076BC (41.9%) 4996BC	5210BC (95.4%) 4952BC	24	780	*Triticum dicoccum*	120-130 cm, elongated pit (black layer)
Poz-161856	6180	40	5208BC (2.1%) 5204BC 5181BC (66.1%) 5061BC	5286BC (1.8%) 5272BC 5218BC (93.7%) 5003BC	24	458	*Fallopia convolvulus (3 x fruits)*	80-90 cm, elongated pit
Poz-135504	6190	35	5210BC (2.5%) 5205BC 5177BC (65.7%) 5068BC	5292BC (3.6%) 5265BC 5220BC (91.8%) 5032BC	18	749	*Triticum dicoccum*	70-80 cm, pit, bottom (with daub, black layer)
Poz-135508	6215	35	5217BC (7.0%) 5206BC 5172BC (61.2%) 5071BC	5302BC (15.9%) 5249BC 5225BC (10.7%) 5197BC 5190BC (68.9%) 5047BC	24	798	*Triticum dicoccum*	120-140 cm, elongated pit (bottom)
Poz-135511	6230	40	5298BC (21.5%) 5258BC 5221BC (8.5%) 5206BC 5170BC (26.3%) 5115BC 5101BC (11.9%) 5074BC	5306BC (42.2%) 5201BC 5185BC (53.3%) 5054BC	25	845	*Triticum dicoccum*	80-90 cm, elongated pit (bottom); 0.2mgC
Poz-135081	6235	35	5299BC (28.6%) 5256BC 5222BC (9.9%) 5207BC 5165BC (22.1%) 5120BC 5096BC (7.6%) 5078BC	5306BC (49.0%) 5203BC 5181BC (46.5%) 5061BC	22	764 bis	*Triticum dicoccum*	80-100, pit (thin black layer)
Poz-135506	6290	40	5309BC (21.3%) 5283BC 5275BC (47.0%) 5217BC	5367BC (92.7%) 5207BC 5159BC (2.8%) 5126BC	22	792	*Triticum dicoccum*	90-100 cm, pit (bottom); 0.27mgC

Table 2

Fabric type	Biskupice, house no. 2	LBK (Lesser Poland)			Short description of fabric types
	III phase	I phase	II phase	III phase	
I	12%	22%	28%	13%	heavy clay, fine-grained, moderately sorted, admixture of organic fragments
II	36%	28%	19%	35%	silty clay, fine-grained, well-sorted, admixture of organic fragments
III	4%	24%	34%	22%	heavy to silty clay, coarse-grained, poorly sorted, admixture of organic fragments and sand
IV	2%	23%	17%	3%	heavy clay, fine-grained, admixture of sedimentary rocks and organic fragments
V	-	3%	1%	2%	heavy to silty clay, coarse-grained, poorly sorted, admixture of sand and organic fragments
VI	28%	-	1%	14%	heavy to silty clay, admixture of grog
VII	18%	-	-	11%	heavy to silty clay, admixture of grog and sand