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TECHNOLOGICAL INDICATORS IN THE POTTERY PRODUCTION OF THE LATE LINEAR POTTERY CULTURE AND THE MALICE CULTURE

ABSTRACT

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This study aimed to reveal the transformations in pottery production in the Linear Pottery culture. In the course of longstanding analyses of archaeological materials from Lesser Poland, a few technological groups of this pottery were distinguished. A significant change in the preparation of ceramic fabrics was recorded in the late LBK phase, namely the Želiezovce phase. The objective of this study was to gather all data and confront it with the most recent findings from the sites of Targowisko and Brzezie. Based on the investigations, it was established that the major indicators of the late LBK phases were the occurrence of grog admixture, a significantly less common application of chaff admixture, and a smaller contribution of ceramic fabrics tempered with sand. In the light of the chronology of the materials under scrutiny, a distinctive predominance of ceramic fabrics with grog admixture was observed when compared with the set of ceramic bodies previously analysed.

Keywords: Neolithic, south-eastern Poland, ceramic technology, Linear Pottery culture, Malice culture
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1. INTRODUCTION

The earliest farming settlements in the territory of Poland were established by communities of the Linear Pottery culture (from German Linearbandkeramik – LBK). The latest studies on absolute chronology for this culture indicate that it existed from 5350-4900/4800 BC within the territory of modern Poland (Czekaj-Zastawny 2014; 2017; Czekaj-Zastawny *et al.* 2020; Oberc *et al.* in press). The beginnings of the classic phase (Ib) of the Malice culture (MC), which is connected with the Lengel and Tisza cultures was established to between 4650-4550 BC (Kadrow *et al.* 2021). The process of cultural succession between the LBK and MC is the subject of considerations by many researchers – artifacts of MC very often are unearthed at the same sites as those of the LBK. Some claimed that with the end of the LBK and Bükk cultures, contacts between south-eastern Poland and the northern part of the Carpathian Basin ceased (Kozłowski *et al.* 2014 (2015), 41), and settlers, *e.g.*, of the MC, came from the Carpathian Basin (Kaczanowska 1990; Kamieńska and Kozłowski 1990; Kozłowski 2004, 11).

Anna Kulczycka-Leciejewiczowa proposed another direction – a gradual change within the LBK community in its late phase (III) (2004, 21). Sławomir Kadrow maintains that this change caused the transformation of the LBK into the MC (Kadrow 2005, 26, 27; Kadrow 2020a, 96-101).

A characteristic trait of these societies was a farming economy based on agriculture and animal husbandry, which was directly associated with a sedentary lifestyle (Wiślański 1969; Kulczycka-Leciejewiczowa 1979; Kozłowski 1998; Pavúk 2004; Czekaj-Zastawny 2008a; Bánffy and Oross 2010; Czekaj-Zastawny 2017). People lived in long, rectangular houses of post construction, concentrated in groups forming farms. Moreover, these societies were the first who produced and utilised ceramic vessels in Lesser Poland. Fragments of these vessels, in addition to flint and stone tools, are the most common artefacts used by the Neolithic farmers that have preserved until today.

Microscopic analyses of ceramic vessels have been used in the elaboration of archaeological ceramic materials for many years. Such analyses of LBK pottery coming from the Upper Vistula River, begun in the early 21st century, have delivered a lot of new findings and detailed knowledge on the matter in question. The basic division of vessels and ceramic fragments of LBK pottery is based on distinguishing thin-, medium- and thick-walled vessels. Thin-walled vessels are characterised by an occurrence of incised ornamentation. Medium- and thick-walled vessels were usually not decorated with this type of ornament. Plastic elements are often encountered on the surfaces of the latter, such as knobs, handles, bands, finger- and nail-tipped decoration, and ornaments of the *barbotino* style (Stadler and Kotova 2019; Czekaj-Zastawny *et al.* 2020, fig. 7: g). Each of the above-mentioned vessel types is also distinctive in terms of the preparation of the ceramic fabric. Generally, the thin-walled vessels were made of fine-grained ceramic fabric, while for the production of medium-walled vessels, medium and coarse-grained fabrics were used.

Table 1. The average content of clay minerals, quartz, and grog in 302 LBK and 48 ALPC ceramic samples (Rauba-Bukowska and Czekaj-Zastawny 2020); values in percent SD (standard deviation)

Cultural affiliation	Type	Average content of			All type	Average content of					
		Clay minerals	Quartz	Grog		Clay minerals	SD	Quartz	SD	Grog	SD
LBK phase I	fine ware	64	22	0,27	all type phase I LBK	65	10	19	10	0,35	1
	kitchen ware	66	18	0,27							
	coarse ware	66	17	0,52							
LBK phase II	fine ware	66	19	0,5	all type phase II LBK	63	16	19	11	0,48	2
	kitchen ware	63	21	0,13							
	coarse ware	59	18	0,62							
LBK phase III	fine ware	56	27	1,5	all type phase III LBK	54	13	27	11	4	6
	kitchen ware	56	28	3,7							
	coarse ware	51	25	8,5							
ALPC	*	*	*	*	all type ALPC	52,7	7,9	28,1	8,5	2,1	4,7

Thick-walled vessels were produced using coarse-grained ceramic fabrics. However, these were not rigid rules that would apply to every case study. Instead, they should be considered as strong tendencies or traditions, whether intentional or not. Detailed studies on ceramic fabrics allowed us to specify the preferences of potters in manufacturing ceramic pots, which include their variability over time and between sites. The analysis consisted of several hundred LBK vessels discovered at a few dozen sites from south-eastern Poland (Czekaj-Zastawny and Rauba-Bukowska 2013; Rauba-Bukowska 2014a; Kozłowski *et al.* 2014 (2015); Rauba-Bukowska 2016; Kadrow and Rauba-Bukowska 2017; Czekaj-Zastawny *et al.* 2017; Rauba-Bukowska and Czekaj-Zastawny 2020). The investigated fragments come from pots of various chronologies within the LBK development timeframes, namely the early (from 5350 BC), classical and late (from 5000-4900/4800 BC) phases. These studies, constantly being complemented with the results of new analyses, constitute the basis for the formulation of conclusions on the variability in the technology of ceramic vessel production (Table 1; Fig. 1). Detailed examinations, *i.a.* statistical analyses of data, revealed that with regard to the investigated samples, pottery from the older LBK phases was made of heavy clays/loams with a lower contribution of silt. Thin-walled vessels mainly were produced using ceramic fabrics with only organic admixture (namely chaff). In con-

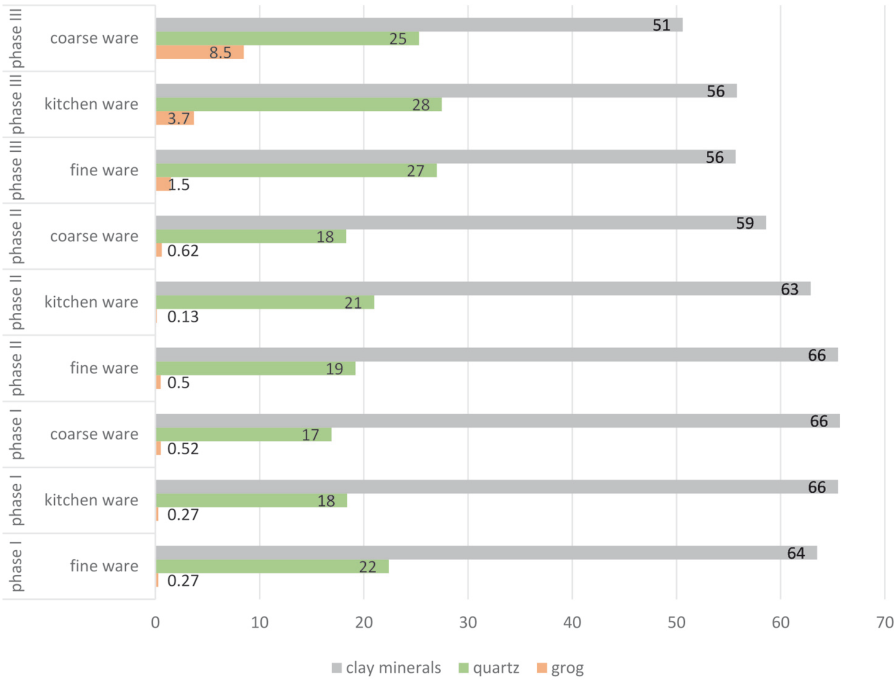

Fig. 1. The average content of clay minerals, quartz, and grog in the LBK sherds (phase I n=99; phase II n=103; phase III n=100) and ALPC (n=48) ceramic samples; value in percent

trast, medium-walled vessels contained sand and plant admixture. Finally, thick-walled vessels were made of ceramic fabrics with chaff admixture and fragments of argillaceous rock fragments, and rarely, with grog (Kadrow and Rauba-Bukowska 2016; Czekaj-Zastawny *et al.* 2017; Rauba-Bukowska and Czekaj-Zastawny 2020). These differences may be due to a few factors: technological, cultural, and aesthetic. In the late LBK phases, silty clays were more commonly used as raw material to produce fine ceramics (Kozłowski *et al.* 2015). Pottery with decorations corresponding to Želiezovce stylistics more often was made of well-prepared ceramic paste. These fabrics usually do not contain organic admixture. Thick-walled vessels were produced using the clay mixtures that previously had been very rarely applied, namely with grog admixture (crushed ceramics). Therefore, distinctive changes had their impact on both the manner of acquisition of raw materials as well as the preparation of ceramic fabrics. These technological changes in the production of pottery most likely resulted from deeper transformations inspired by internal social mechanisms and/or by external influences induced by contacts with societies of different traditions (*i.a.*, technological preferences in the production of pottery).

In this period (late LBK in Poland), contacts with the communities inhabiting the territories of eastern Slovakia have been confirmed (Czekaj-Zastawny 2008a; 2008b; Kaczanowska and Godłowska 2009). They represent the eastern variant of the LBK, namely the Eastern Linear cultural circle or the Alföld Linear Pottery culture (ALPC). ALPC artefacts have been recorded in the territory of Poland at LBK settlements as well. Especially noteworthy are objects (tools) made of obsidian. This raw material is not available in the vicinity of the LBK settlements in Poland, whereas it is a common raw material within the area occupied by ALPC societies (Szeliga 2021; Werra *et al.* 2021). Apart from obsidian, at LBK settlements such as Mogiła 62, Brzezie 17, Tominy 6, Zwięczyca 3, Kosina 62, and Rzeszów 16 (city District Piastów), numerous fragments of vessels were encountered that closely resemble the vessels gathered at ALPC sites in terms of both ornament stylistics and technology (Kadrow 1990; Szeliga and Zakościelna 2007; 2019; Kaczanowska and Godłowska 2009; Czekaj-Zastawny 2014; Dębiec 2014; Sebők 2014; Dębiec *et al.* 2021).

Analyses of the composition of ceramic fabrics applied by these two cultural units (LBK and ALPC) revealed a similarity between the ceramic materials used in the pottery production of the Želiezovce phase in Poland and the ALPC pottery manufacturing tradition (Kozłowski *et al.* 2015; Rauba-Bukowska 2014b; Moskal-del Hoyo *et al.* 2017; Czekaj-Zastawny *et al.* 2018; Rauba-Bukowska and Czekaj-Zastawny 2020). This similarity refers to the technology of preparation of ceramic fabrics, namely the selection of raw material and admixtures. Silty, fine-grained clays were often used as the raw material, and grog admixture became more common. Pottery of the Bükk culture from Hungary corresponds in this respect to the pottery from eastern Slovakia. Thin-walled vessels are generally characterised by a fine-grained, compact, homogeneous fabric. The raw material is assumed to have been carefully selected and prepared; ceramic fabrics were not artificially tempered (Szilágyi *et al.* 2011; 2014).

The Želiezovce phase itself derived from the Želiezovce group formed in the territory of modern western Slovakia (Pavúk 1969; Kadrow 2020b). Ceramic materials of this group were characterized by the use of silty clays and the lack of organic admixture (Pavúk 1969).

The materials of both the Želiezovce phase in south-eastern Poland and the Želiezovce group in Slovakia (*e.g.*, site Štúrovo) often are accompanied by imported artefacts. Within the Želiezovce group, these artefacts come from the Tisza River region and from the area of the Szakálhát group, and numerous imports come from the Bükk culture (Pavúk 1969, 275; Pavúk 1994, 172, 173; Müller-Scheeβel *et al.* 2020, 105). In the Želiezovce phase in Poland, they were imported from the Tiszadob-Kapušany groups and the Bükk culture as well (Kadrow 1990; Kaczanowska and Godłowska 2009; Czekaj-Zastawny 2014; Dębiec 2014; Szeliga and Zakościelna 2007; 2019; Szeliga 2021).

The above remarks may suggest the main directions from which technological innovations (in pottery production) could have emanated: a formative area for ceramics in the Želiezovce style, and areas south of the Carpathians – inhabited by the population of the Eastern Linear cultural circle (Kulczycka-Leciejewiczowa 1979, 63; Rauba-Bukowska and Czekaj-Zastawny 2020).

2. MATERIALS, AIMS, AND AREA OF RESEARCH

The newest microscopic analyses covered 47 fragments of pottery (Table 2). Thirty fragments come from LBK vessels, including 15 pieces from Brzezie 40 and another 15 from Targowisko 16. Almost half of these fragments are the remains of thin-walled vessels; the other half represents thick- and medium-walled vessels. Seventeen fragments were ascribed to the MC and were collected from Targowisko 14-15, including eight thin-walled and nine thick-walled fragments. All of these specimens were gathered during excavations carried out in the years 2018-2019, when the relics of households of the LBK and the MC were discovered. These households were contemporaneous and preserved in an undisturbed condition (Kadrow *et al.* 2021).

The studies on prehistoric pottery were complemented with the results of investigations and analyses of ceramic raw materials. For this purpose, samples from a few locations were taken (Fig. 2; Table 2). These samples were subject to evaluation already at the stage of field research, and based on the results, some of them were not included in further analyses. More promising were the samples taken from the accumulation terraces of the Raba River, to the east of the complex of sites in Targowisko, as well as the samples coming from the area situated to the south of Brzezie 40, nearby an unnamed stream of water.

Table 2. List of analysed samples

No	Symbol	Site	Samples	Cultural affiliation	Phase	Inv. no	Feature	Fine/ middle/ coarse
1	Brz40/1	Brzezie 40	Neolithic ceramic	LBK	II/III	2018/61	10	fine
2	Brz40/2	Brzezie 40	Neolithic ceramic	LBK	II/III	2018/67	10	fine
3	Brz40/3	Brzezie 40	Neolithic ceramic	LBK	II/III	2018/54	10	middle
4	Brz40/4	Brzezie 40	Neolithic ceramic	LBK	II/III	2018/32	8	fine
5	Brz40/5	Brzezie 40	Neolithic ceramic	LBK	II/III	2018/52	10	fine
6	Brz40/6	Brzezie 40	Neolithic ceramic	LBK	II/III	2018/52	10	coarse
7	Brz40/7	Brzezie 40	Neolithic ceramic	LBK	II/III	2018/29	10	fine
8	Brz40/8	Brzezie 40	Neolithic ceramic	LBK	II/III	2018/29	10	coarse
9	Brz40/9	Brzezie 40	Neolithic ceramic	LBK	II/III	2018/30	10	middle

Table 2.

No	Symbol	Site	Samples	Cultural affiliation	Phase	Inv. no	Feature	Fine/ middle/ coarse
10	Brz40/10	Brzezie 40	Neolithic ceramic	LBK	II/III	2018/44	8	coarse
11	Brz40/11	Brzezie 40	Neolithic ceramic	LBK	II/III	2018/39	10	fine
12	Brz40/12	Brzezie 40	Neolithic ceramic	LBK	II/III	2018/39	10	middle
13	Brz40/13	Brzezie 40	Neolithic ceramic	LBK	II/III	2018/28	10	coarse/middle
14	Brz40/14	Brzezie 40	Neolithic ceramic	LBK	II/III	2018/40	8	coarse
15	Brz40/15	Brzezie 40	Neolithic ceramic	LBK	II/III	2018/71	10	coarse
16	Tar16/1	Targowisko 16	Neolithic ceramic	LBK	III	2018/62	44	fine/middle
17	Tar16/2	Targowisko 16	Neolithic ceramic	LBK	III	2018/62	44, 45	coarse
18	Tar16/3	Targowisko 16	Neolithic ceramic	LBK	III	2018/17	31	fine
19	Tar16/4	Targowisko 16	Neolithic ceramic	LBK	III	2018/17	31	fine
20	Tar16/5	Targowisko 16	Neolithic ceramic	LBK	III	2018/60	45	fine
21	Tar16/6	Targowisko 16	Neolithic ceramic	LBK	III	2018/20	31	fine
22	Tar16/7	Targowisko 16	Neolithic ceramic	LBK	III	2018/65	45	fine
23	Tar16/8	Targowisko 16	Neolithic ceramic	LBK	III	2018/13	44	fine
24	Tar16/9	Targowisko 16	Neolithic ceramic	LBK	III	2018/73	44	fine
25	Tar16/10	Targowisko 16	Neolithic ceramic	LBK	III	2018/12	44	coarse
26	Tar16/11	Targowisko 16	Neolithic ceramic	LBK	III	2018/34	31	coarse
27	Tar16/12	Targowisko 16	Neolithic ceramic	LBK	III	2018/34	31	fine/middle
28	Tar16/13	Targowisko 16	Neolithic ceramic	LBK	III	2018/38	31	coarse
29	Tar16/14	Targowisko 16	Neolithic ceramic	LBK	III	2018/14	31	coarse
30	Tar16/15	Targowisko 16	Neolithic ceramic	LBK	III	2018/58	44	coarse
31	Tar14-15/1	Targowisko 14-15	Neolithic ceramic	Malice culture		2019/33	1/A	fine

Table 2.

No	Symbol	Site	Samples	Cultural affiliation	Phase	Inv. no	Feature	Fine/ middle/ coarse
32	Tar14-15/2	Targowisko 14-15	Neolithic ceramic	Malice culture		2019/33	1/A	coarse
33	Tar14-15/3	Targowisko 14-15	Neolithic ceramic	Malice culture		2019/72	1/B	fine
34	Tar14-15/4	Targowisko 14-15	Neolithic ceramic	Malice culture		2019/80	1/B	fine
35	Tar14-15/5	Targowisko 14-15	Neolithic ceramic	Malice culture		2019/114	1/B	coarse
36	Tar14-15/6	Targowisko 14-15	Neolithic ceramic	Malice culture		2019/114	1/B	fine
37	Tar14-15/7	Targowisko 14-15	Neolithic ceramic	Malice culture		2019/39	1/C	coarse
38	Tar14-15/8	Targowisko 14-15	Neolithic ceramic	Malice culture		2019/43	1/C	coarse
39	Tar14-15/9	Targowisko 14-15	Neolithic ceramic	Malice culture		2019/44	1/C	fine
40	Tar14-15/10	Targowisko 14-15	Neolithic ceramic	Malice culture		2019/44	1/C	fine
41	Tar14-15/11	Targowisko 14-15	Neolithic ceramic	Malice culture		2019/44	1/C	coarse
42	Tar14-15/12	Targowisko 14-15	Neolithic ceramic	Malice culture		2019/44	1/C	coarse
43	Tar14-15/13	Targowisko 14-15	Neolithic ceramic	Malice culture		2019/115	1D part B	fine
44	Tar14-15/14	Targowisko 14-15	Neolithic ceramic	Malice culture		2019/55	1/C	fine
45	Tar14-15/15	Targowisko 14-15	Neolithic ceramic	Malice culture		2019/92	1/D	coarse
46	Tar14-15/16	Targowisko 1 4-15	Neolithic ceramic	Malice culture		2019/93	1/D	coarse
47	Tar14-15/17	Targowisko 14-15	Neolithic ceramic	Malice culture		2019/51	2	coarse
48	Sur45	Targowisko	ceramic raw material	clay				
49	Sur46	Targowisko	ceramic raw material	clay				
50	Sur47	Brzezie	ceramic raw material	clay				
51	Sur48	Brzezie	ceramic raw material	clay				

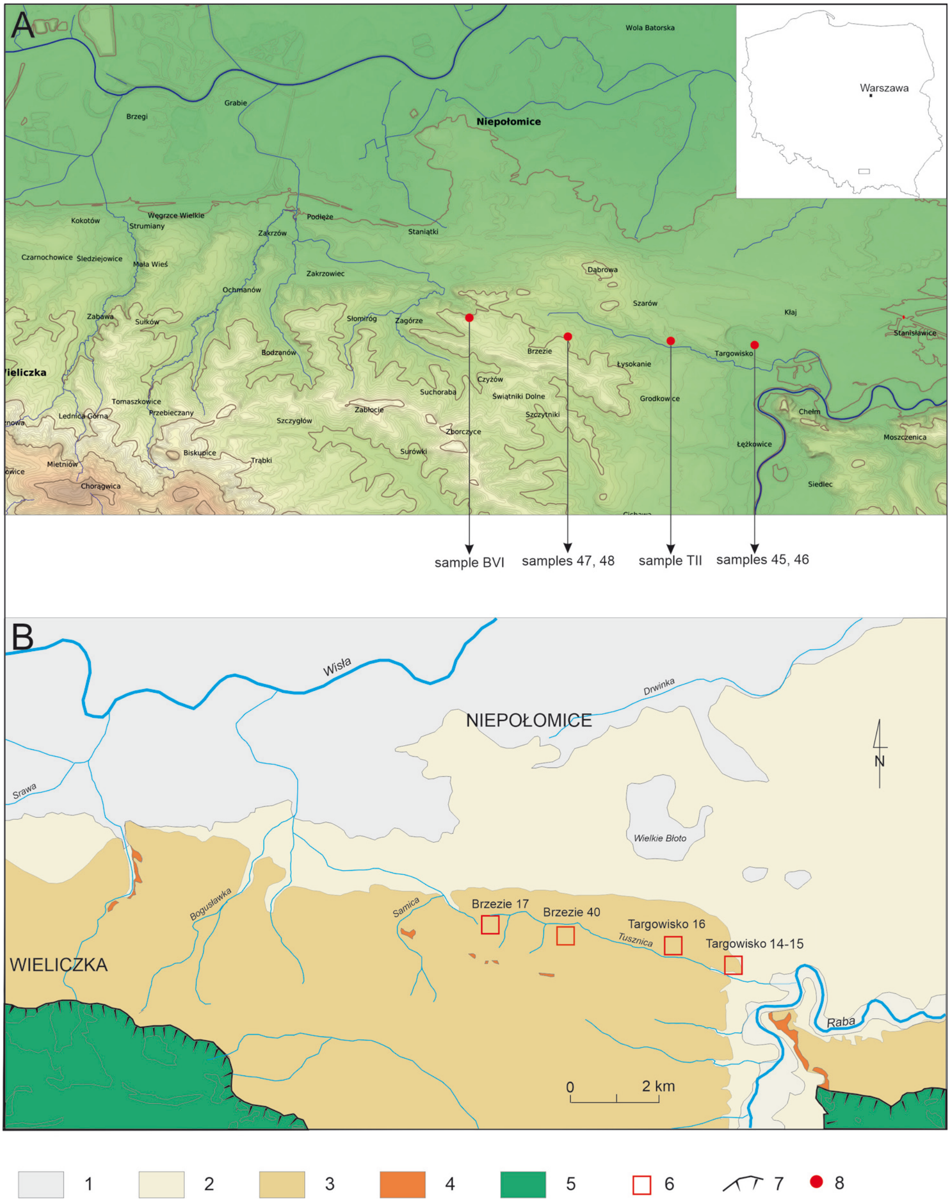

Fig. 2. Location of the archaeological sites and samples of raw material.
A – physical map of south-eastern Poland; B – selection of geological maps (simplified, after Burtan 1954; Skoczylas-Ciszewska and Burtan 1954; Gradziński 1955); 1 – muds, sands and gravels of floodplains of the Vistula and Raba Rivers, Holocene; 2 – sands and gravels above the floodplain terrace of the Vistula and Raba Rivers, Pleistocene; 3 – loess, Pleistocene; 4 – Chodenice and Grabowiec Beds, Miocene; 5 – Carpathian flysch, Paleogene, Cretaceous; 6 – location of the sites; 7 – contemporary margin of the Carpathians; 8 – location of raw material sampling

The analysis aimed to identify the mineral and petrographic composition of ceramic fabrics and the degree of their mixing. In the following stage of the studies, the series of fragments under investigation were compared one to another and confronted with the existing data on the technology of pottery production in the LBK in Lesser Poland.

3. RESEARCH METHODOLOGY

From the ceramic sherds, thin sections were analysed by microscope under polarised light. The raw material samples were mixed by hand and then small bricks of approx. 7 × 5 × 2 cm were shaped. The clay samples prepared in this way were dried for 5 hours at a temperature of 150°C. Then, they were fired in an electric kiln for 24 hours in an oxidizing atmosphere at temperature 700°C. After cooling down, thin sections were made, analogous to those from Neolithic ceramics.

Using the point counting techniques, the percentages of certain compounds were established, including, among others: 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. The description of mineral composition also included silty grains and voids (pores, cavities). The percentage of these elements was established for every sample. The petrographic description also included the degree of mixing of the ceramic fabric, as well as the temperature and conditions of the firing process. An approximate temperature of the original firing was determined based on the thermal transformations of clay minerals, namely the observation of the degree of transformation of ceramic matrix into an amorphous, isotropic substance and the observation of biotite minerals, hornblende, and glauconite (Bolewski and Żabiński 1988; Quinn 2013, 190-203). The division of grain fractions assumed in this paper followed the determinations formulated by the Soil Science Society of Poland (Polskie Towarzystwo Gleboznawcze 2009). The data collected was used for comparative studies.

4. RESULTS

4.1. Raw materials

The research area has thus far delivered a significant collection of ceramic raw materials, including samples of older clays of the Miocene Age, loess (the most common sediment in this area), river sediments, as well as the soils covering the ground. This collection was gathered over the last dozen or so years (Rauba-Bukowska *et al.* 2007; Rauba-Bukowska 2014c; Rauba-Bukowska 2019). The current studies have complemented the collection with new samples (samples 45, 46, 47, 48). All of these raw materials were obtained

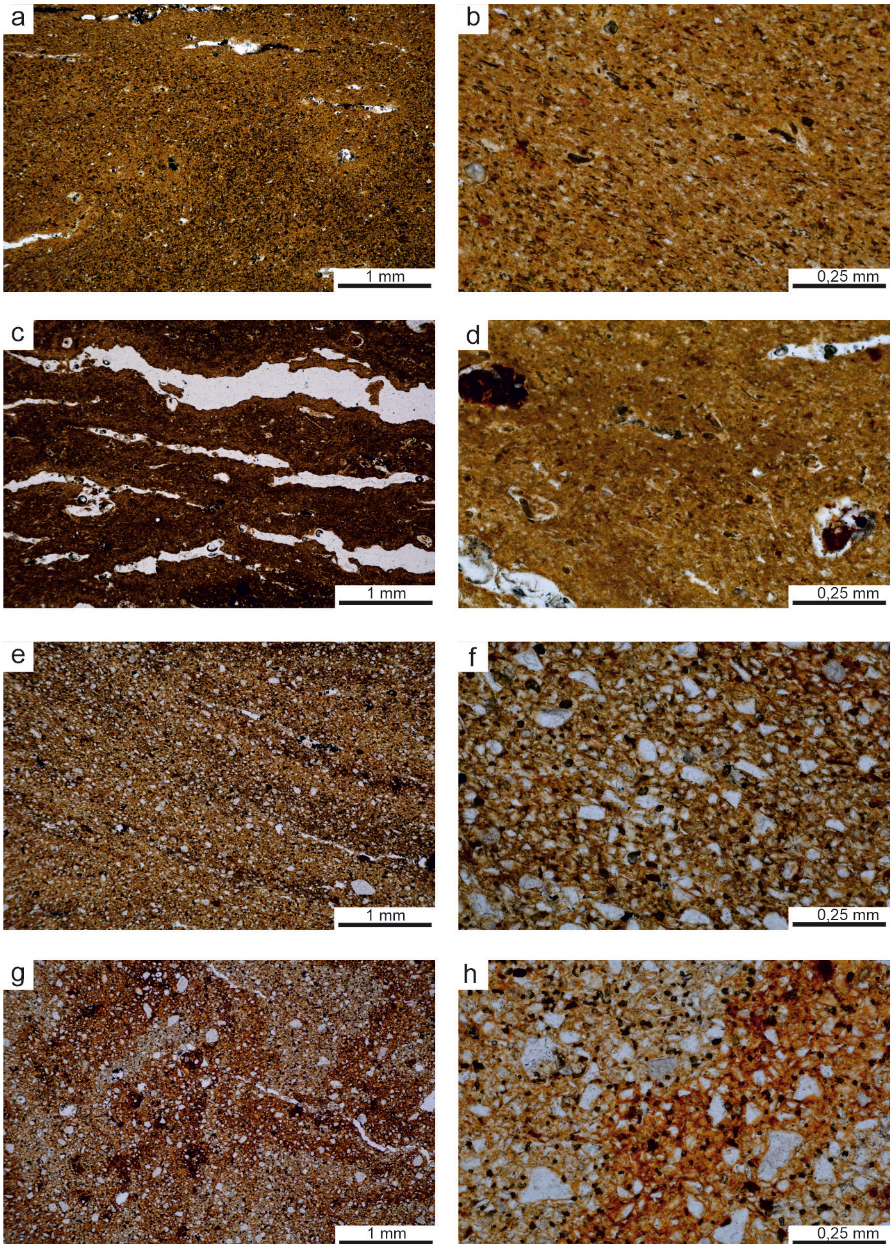

Fig. 3. Photomicrographs of thin sections;
a, b – sample Sur45, homogeneous clay, rare parallel microcracks in the ceramic body; c, d – sample Sur46, homogeneous clay with numerous parallel microcracks; e, f – sample Sur47, silty clay, or loess-like raw material, parallel colorations; g, h – sample Sur48, silty clay or loess-like raw material, uneven colorations; all photos in Plane Polarized Light (PPL)

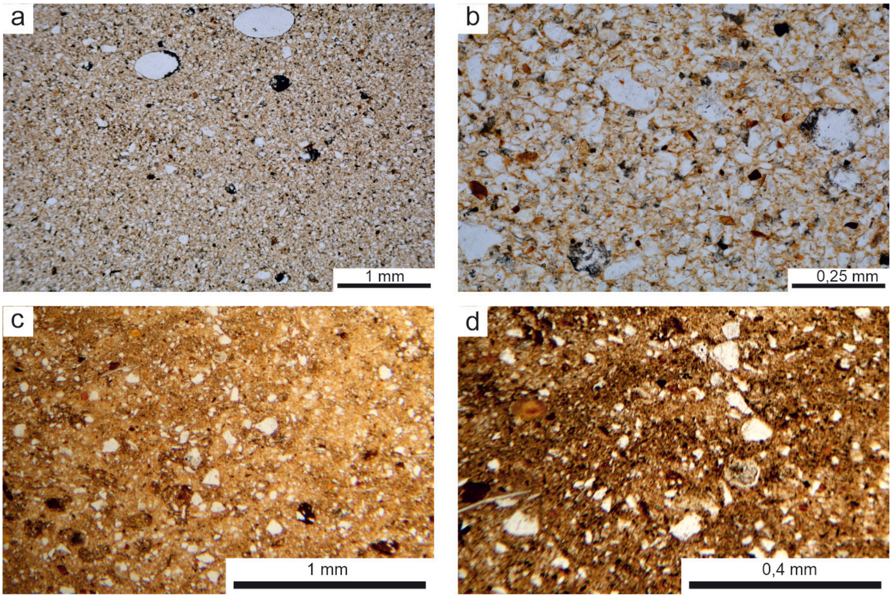

Fig. 4. Photomicrographs of thin sections;
a, b – sample SurTII, loess-like raw material, homogeneous, very fine-grained; c, d – sample SurBVI, heavy clay with a few coarser grains, rare grains of glauconite; all photos in Plane Polarized Light (PPL)

through the Edelman auger used for manual drilling in geological surveys. The locations and descriptions of the samples that could have been used as sources of ceramic raw materials are given below.

Clays and gravels of the lower accumulation terraces, Pleistocene, samples 45, 46 (Fig. 2; 3: a, b, c, d). The samples were taken from the vast valley of the Raba River. This area is adjacent to the silty clays of the Pleistocene Age, extending to the west. The samples were obtained from a depth of *ca.* 1 and 1.7 meters below the ground level. The drilling was performed until it reached the groundwater level. The samples consisted of dark grey, flexible clays containing well-preserved plant remains.

The raw material is fine-grained and homogenous. The sample consisted mainly of clay minerals (*ca.* 70-80%) with a low content of silty grains. There were visible non-transparent compounds, concentrations of iron oxides and hydroxides. The firing process caused an occurrence of longitudinal micro-cracks (Fig. 3: c, d).

River accumulation deposits covering the valleys and the lowest terraces, Holocene, samples 47, 48 (Fig. 2; 3: e, f, g, h).The samples were gathered on the northern slope of a small elevation in Brzezie village, located along the road heading to Dąbrowa. Within the neighbourhood of the sampling spot, there is a small water reservoir. The samples consisted of grey silty clays up to a depth of *ca.* 1 m, and yellow-grey and grey silty clays below

1 m. The drilling was performed until it reached the groundwater level, down to a depth of *ca.* 1.8-2.0 meters. The surroundings of this area are covered with loess-like clays.

The microscopic images of the samples reveal a structure, composition, and granulometry that is typical of loess and loess-like clays. The major compounds of the samples are the binding substance (clay minerals) and silty grains. The latter are represented mainly by quartz and feldspars, non-transparent grains, and mica. There were also distinctive accumulations and concentrations of ferruginous components within the structure, namely iron oxides and hydroxides.

In the course of the former investigations on ceramic raw materials, some samples were taken from the river sediments of the Tusznica Stream, nearby the complex of archaeological sites in Targowisko (sample TII), as well as from the Miocene clays in the vicinity of Brzezie 17 (sample BVI; Fig. 2; Rauba-Bukowska 2007; Rauba-Bukowska 2014c).

Fluvial sediments, Holocene, sample TII (Fig. 2; 4: a, b). The material was sampled from a sounding trench established *ca.* 300 m to the south of the archaeological site Targowisko 16, within a distance of 20 m from the Tusznica Stream, which separates two flattened elevations. The area of the sampling spot belongs to the flood plain. This material is of light grey-brown colour with rusty discolorations.

After firing the clay substance is light orange. It consists of thermally altered clay minerals and a significant amount of silty grains. Within the fine-grained substance, there are sporadic larger, rounded grains of quartz and feldspars. There are also very tiny (0.02 mm) opaque minerals, evenly dispersed. There are also small voids. Rarely, the substance contains concentrations of iron oxides and hydroxides – regular in shape, with distinctive edges (Rauba-Bukowska 2007).

Marine clays of Miocene age, sample BVI (Fig. 2; 4: c, d). The ceramic raw material (clay) was sampled from the northern slope of a small elevation located *ca.* 200 m to the south of the archaeological site Brzezie 17. The samples of flexible grey-to-light-grey clay were taken from a depth of 30 cm.

After firing the clay is orange in colour. It consists mainly of thermally altered clay minerals and a small number of silty grains. Sporadically, there are also larger, rounded grains of quartz and feldspars noted. Within the matrix, concentrations of iron oxides and hydroxides are distinctive. They occur in two types. One of these types is represented by small (up to 0.5 mm) concentrations, regular in shape, with distinct edges. The other occurs in the form of wide, rusty bands. The substance also contains a few thermally altered grains of glauconite. Within the sample, numerous elongated voids were observed, which must have emerged due to the cracking of the material during the process of firing (Rauba-Bukowska 2007).

Based on the above-discussed findings, it may be concluded that both the Miocene clays (sample BVI), as well as the clays from the Raba River (samples 45 and 46), are suitable for the production of ceramic vessels. Due to their poor adhesiveness and elasticity, loess sediments are not very amenable to the shaping of vessel-like forms in the technology of hand-made pottery.

4.2. Pottery

Mineral composition

Ceramic fabrics consist of clay minerals (40-75%), silty grains (approx. 5-20%), tiny mica flakes (muscovite, biotite), iron oxides and hydroxides, opaque minerals and rare heavy minerals (Table 3). Larger grains within the substance are represented by quartz grains, potassium feldspars, and a few chalcedony grains. With regard to the set of samples under analysis, fragments of rocks occur scarcely within the matrix. Amongst them, the most commonly encountered are fragments of sedimentary rocks (mainly claystone and mudstone). Fragments of igneous and metamorphic rocks are very rare, but were found in a greater amount in sample no. 11 from Targowisko 16, for example. Crystal grains are rounded (this concerns both mineral grains and rock fragments). The samples also contained other compounds, the contribution of which was not determined as a percentage. These were grains of glauconite and remains of plankton. Chunks of grog were significant elements of ceramic fabrics, which is discussed in greater detail in the section addressing the issue of intentional admixtures.

4.3. Identification of ceramic raw materials used in production of prehistoric pottery

As a result of the conducted studies upon both ceramic raw materials and prehistoric pottery, it was determined that for the production of ceramic vessels, clays from the Raba River had not been used in their pure form. The analysed clay samples revealed a very homogenous clay substance, with a scarce amount of mineral compounds. None of the vessels under scrutiny shared these characteristics. Moreover, there were no vessels made of purely loess material.

The major indicators used for the determination of the clay were grains of glauconite and the remains of plankton, identified within the ceramic fabrics encountered at the sites Targowisko 16 and 14-15 (Fig. 5: a, b). These compounds indicate that the raw material for the production of ceramic vessels was Miocene clay. The Miocene clay outcrops are situated nearby the archaeological sites on the right bank of the Vistula River, such as Zagórze 2, Brzezie, and Targowisko. Outcrops of Neogene (Miocene) sediments are also commonly encountered on the left bank of the Vistula River, including in the vicinity of Zesławice (there was a brickyard and open-pit mining was carried out). Pottery made of clay containing glauconite and the remains of plankton was identified at a few sites situated on the left bank of the Vistula River, such as Modlnica 5, Mogiła 62, and Pleszów 17-20 (Czekaj-Zastawny and Rauba-Bukowska 2013).

Based on these facts, it should be concluded that ceramic vessels from the sites Targowisko 16 and 14-15 were most likely made of a mixture of the Miocene clays and other sediments, whereas a great majority of the analysed series of 15 fragments of pottery from

Table 3. Mineral composition of the samples; temperature in degrees Celsius; red – reduction, redox – reduction with low airflow; ox – oxidation; values in percent

No	Symbol of the site	Clay minerals	Silt (grains <0,05 mm)	Quartz	Flint/Chalcedony	K-feldspars	Plagioclases	Fragments of sedimentry rocks	Fragments of magmatic rocks	Fragments of metamorphic rocks	Muscovite	Biotite	Opaque minerals	Iron oxides and hydroxides	Grog	Clay clasts	Organic fragments	Heavy minerals	Voids	Fine/middle/coarse	Atmosphere of the firing	Approximately temperature of firing	Ceramic fabric type
1	Brz40/1	58,6	20,5	3,6	0,0	1,3	0,0	0,3	0,0	0,0	5,1	5,4	2,3	0,5	0,0	0,8	0,1	0,0	1,8	fine	redox	700-750	2
2	Brz40/2	52,8	13,6	15,8	0,0	0,7	0,0	0,0	0,2	0,7	0,5	0,0	1,2	0,2	6,6	1,2	1,0	0,2	5,1	fine	redox	700-750	7
3	Brz40/3	67,3	12,3	2,8	0,1	0,6	0,0	0,0	0,0	0,0	0,6	0,0	0,3	1,3	0,0	1,9	4,4	0,0	8,5	middle	red	700-750	4
4	Brz40/4	54,6	14,2	9,9	0,1	1,8	0,0	3,5	0,0	0,0	0,4	1,4	0,7	0,7	7,1	0,7	0,0	0,0	5,0	fine	red	700-750	7
5	Brz40/5	54,3	13,3	6,6	0,0	0,7	0,0	18,9	0,0	0,0	1,7	0,2	0,2	1,5	0,0	0,5	0,0	0,0	2,0	fine	redox	700-750	4
6	Brz40/6	57,9	11,5	5,8	0,0	1,8	0,0	0,0	0,0	0,0	0,9	0,0	0,3	0,0	7,6	0,0	1,2	0,0	13,0	coarse	redox	800	6
7	Brz40/7	45,8	13,2	10,2	0,0	1,4	0,0	1,7	0,0	0,0	0,0	0,3	0,3	0,7	20,3	0,7	0,0	0,0	5,4	fine	redox	700-750	7
8	Brz40/8	60,2	8,8	4,9	0,1	1,5	0,0	3,0	0,0	0,0	0,0	0,0	2,1	2,1	6,1	4,3	0,0	0,0	7,0	coarse	redox	700-750	6
9	Brz40/9	58,7	5,3	16,8	1,4	0,3	0,0	2,2	0,0	0,1	0,0	0,0	0,3	1,1	0,3	1,7	2,8	0,0	9,2	middle	red	700-750	3
10	Brz40/10	62,1	8,6	4,9	0,3	0,0	0,0	4,3	0,0	0,0	0,3	0,0	1,2	3,1	0,0	1,5	1,2	0,0	12,5	coarse	redox	700-750	4
11	Brz40/11	61,9	16,2	10,0	0,1	0,3	0,0	4,1	0,0	0,0	1,4	1,0	0,3	0,3	0,0	0,0	0,0	0,0	4,5	fine	redox	700-750	3
12	Brz40/12	55,9	20,2	6,0	0,3	0,8	0,0	0,0	0,3	0,3	1,0	1,0	0,3	0,8	6,3	4,2	0,1	0,0	2,6	middle	redox	750	7
13	Brz40/13	48,5	10,3	23,5	0,1	2,4	0,0	2,6	0,0	0,1	0,6	0,6	0,9	1,2	1,5	1,2	0,3	0,0	6,5	coarse/middle	redox	700-750	7
14	Brz40/14	44,1	19,0	16,7	0,0	1,5	0,0	0,8	0,0	0,1	1,0	0,8	1,0	0,8	5,6	0,5	2,0	0,0	6,3	coarse	redox	750	7
15	Brz40/15	59,8	16,0	7,6	0,0	0,3	0,0	0,0	0,0	0,0	1,3	0,3	0,3	4,2	0,3	1,3	3,4	0,0	5,2	coarse	redox	700-750	3

Table 3.

No	Symbol of the site	Clay minerals	Silt (grains <0,05 mm)	Quartz	Flint/Chalcedony	K-feldspars	Plagioclases	Fragments of sedimentry rocks	Fragments of magmatic rocks	Fragments of metamorphic rocks	Muscovite	Biotite	Opaque minerals	Iron oxides and hydroxides	Grog	Clay clasts	Organic fragments	Heavy minerals	Voids	Fine/middle/coarse	Atmosphere of the firing	Approximately temperature of firing	Ceramic fabric type
16	Tar16/1	61,7	14,0	2,7	0,0	1,1	0,0	1,9	0,0	0,0	2,7	0,0	0,8	1,9	6,1	2,3	0,0	0,0	4,9	fine/middle	redox	700-750	7
17	Tar16/2	62,6	5,8	2,2	0,0	1,1	0,0	0,8	0,0	0,0	1,6	0,5	0,3	3,3	12,6	2,5	0,0	0,0	6,6	coarse	redox	700-750	4
18	Tar16/3	73,5	14,3	1,1	0,0	0,0	0,0	6,1	0,0	0,0	1,3	0,0	0,8	0,8	0,0	0,0	0,0	0,0	2,1	fine	ox	700-750	1
19	Tar16/4	44,5	13,0	5,7	0,0	1,7	0,0	0,0	0,0	0,0	0,8	0,0	0,0	1,7	20,1	1,7	0,3	0,0	10,5	fine	redox	700-750	7
20	Tar16/5	61,8	17,9	10,1	0,0	1,2	0,0	0,6	0,0	0,0	0,9	0,0	0,6	0,3	3,6	0,3	0,3	0,0	2,4	fine	ox	750	2
21	Tar16/6	73,5	18,5	0,8	0,0	0,3	0,0	0,0	0,0	0,0	1,3	0,0	1,3	0,8	0,0	1,6	0,8	0,0	1,1	fine	red	700-750	2
22	Tar16/7	74,8	11,6	0,0	0,0	0,3	0,0	0,0	0,0	0,0	0,3	0,0	0,0	0,0	1,0	3,5	4,2	0,0	4,5	fine	red	750-850	2
23	Tar16/8	74,9	9,0	2,7	0,0	0,0	0,0	2,7	0,0	0,0	1,4	0,0	0,0	1,9	3,0	1,1	1,1	0,0	2,2	fine	redox	700	4
24	Tar16/9	55,4	10,4	6,5	0,0	0,8	0,0	5,9	0,0	0,0	0,6	0,0	0,3	0,8	11,2	0,8	2,8	0,0	4,5	fine	redox	700-750	6
25	Tar16/10	57,1	11,0	13,3	0,1	0,6	0,0	4,9	0,0	0,6	0,0	0,0	0,3	0,0	9,2	0,3	0,0	0,1	2,9	coarse	redox	700-750	3
26	Tar16/11	64,4	8,4	6,2	0,3	1,1	0,0	0,0	0,0	3,1	0,6	0,0	0,0	0,3	5,9	0,0	1,7	0,0	8,1	coarse	redox	700-750	7
27	Tar16/12	59,9	15,5	8,5	0,6	1,9	0,0	1,6	0,0	0,0	0,9	0,3	0,0	1,9	1,3	6,6	0,0	0,0	0,9	fine/middle	redox	700-750	3
28	Tar16/13	63,8	10,0	5,0	0,0	1,8	0,0	0,7	0,0	0,0	1,4	0,0	0,0	1,8	7,2	3,6	0,0	0,0	4,7	coarse	redox	700-750	6
29	Tar16/14	49,4	8,4	5,6	0,1	0,3	0,0	0,0	0,0	0,0	0,3	0,1	0,3	0,0	27,5	0,0	0,1	0,0	8,1	coarse	redox	700-750	7
30	Tar16/15	51,6	15,5	2,9	0,0	0,0	0,0	4,6	0,0	0,0	1,1	0,0	0,3	0,0	20,3	0,0	0,3	0,0	3,4	coarse	redox	700-750	6

31	Tar14-15/1	53,5	16,9	8,0	0,0	1,5	0,0	1,8	0,0	1,8	1,5	0,0	0,3	0,6	7,4	0,0	0,9	0,0	5,5	fine	redox	700-750	7
32	Tar14-15/2	53,7	11,8	8,4	0,0	1,0	0,0	0,0	0,0	0,0	3,1	0,0	0,0	1,0	17,1	0,7	0,0	0,0	3,1	coarse	redox	700-750	7
33	Tar14-15/3	55,9	11,0	2,9	0,0	0,4	0,0	3,3	0,0	0,0	4,4	0,0	0,4	0,0	19,5	0,4	0,4	0,0	1,5	fine	red	700-750	7
34	Tar14-15/4	58,1	9,6	4,2	0,0	0,0	0,0	0,0	0,0	0,0	2,5	0,0	0,6	0,0	21,1	0,3	0,0	0,0	3,7	fine	redox	700-750	6
35	Tar14-15/5	49,4	11,1	2,6	0,0	0,4	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,4	28,9	1,3	0,0	0,0	6,0	coarse	redox	700-750	6
36	Tar14-15/6	69,4	12,6	4,7	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,3	0,3	0,0	7,6	1,7	0,0	0,0	2,3	fine	redox	800-850	6
37	Tar14-15/7	45,7	15,6	4,4	0,0	1,3	0,0	0,0	0,0	0,0	1,3	0,0	0,0	0,3	27,6	0,6	0,3	0,0	2,9	coarse	redox	700-750	6
38	Tar14-15/8	43,1	13,8	1,5	0,0	0,4	0,0	0,0	0,0	0,0	0,0	0,0	1,5	0,0	32,7	0,4	0,0	0,0	6,7	coarse	red	700-750	6
39	Tar14-15/9	52,9	14,7	10,5	0,0	2,1	0,0	0,0	0,0	0,0	3,9	0,0	0,6	0,0	9,9	0,3	0,0	0,0	5,1	fine	red	800-850	6
40	Tar14-15/10	60,6	13,9	6,1	0,2	1,7	0,0	0,0	0,0	0,0	2,2	0,0	0,0	0,0	11,1	0,0	0,2	0,0	4,4	fine	red	750-800	6
41	Tar14-15/11	57,1	14,7	4,3	0,1	0,3	0,0	0,0	0,0	0,0	1,7	0,0	1,2	0,9	15,6	0,0	0,1	0,0	4,3	coarse	redox	700-750	6
42	Tar14-15/12	41,8	13,9	4,8	0,0	0,4	0,0	0,0	1,1	0,0	2,2	0,0	0,0	0,0	30,0	0,7	0,0	0,0	5,1	coarse	redox	700-750	6
43	Tar14-15/13	59,6	16,4	4,7	0,0	0,0	0,0	0,0	0,0	0,0	1,4	0,0	0,0	0,0	10,8	1,9	0,5	0,0	4,7	fine	redox	700-750	7
44	Tar14-15/14	65,0	13,3	2,4	0,0	0,3	0,0	0,0	0,0	0,0	1,4	0,0	0,7	0,3	11,2	1,4	0,1	0,0	4,1	fine	redox	700-750	6
45	Tar14-15/15	50,5	15,1	5,4	0,0	0,3	0,0	0,0	0,0	0,0	4,0	0,0	0,5	0,5	20,2	0,3	0,0	0,3	3,0	coarse	redox	700-750	6
46	Tar14-15/16	47,5	10,7	5,2	0,0	0,6	0,0	0,0	0,0	0,0	2,3	0,0	0,6	1,4	20,6	0,3	0,0	0,3	10,4	coarse	redox	700-750	6
47	Tar14-15/17	39,9	14,2	5,6	0,0	0,0	0,0	0,0	0,0	0,0	4,3	0,0	0,9	5,6	18,5	0,0	0,0	0,0	11,2	coarse	ox	750	6

Brzezie 40 were produced of clays and silty clays, without glauconite or plankton remains (Fig. 5: c, d). However, two fragments, namely samples Brz40/8 and Brz40/9, were made of ceramic fabrics, within which numerous grains of glauconite were detected; moreover, the sample Brz40/9 additionally contained chunks of chalcedony (Fig. 5: e, f). This suggests another source of raw material. Particularly noteworthy within this series of samples is Brz40/1, which contained tiny biotite flakes in a greater amount than was recorded for

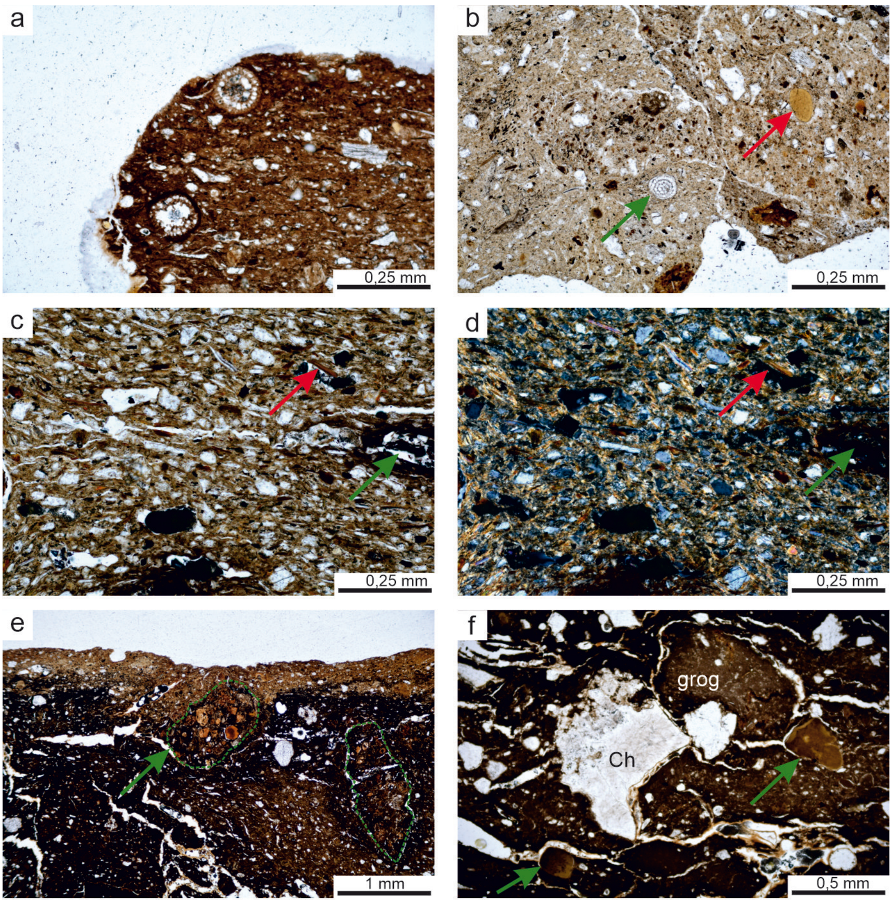

Fig. 5. Photomicrographs of thin sections; a – sample Tar16/1, two microfossils close to the outer surface of vessels (*Diatoms or Radiolaria*?), PPL; b – sample Tar14-15/2, microfossils (green arrow) and grains of glauconite (red arrow), PPL; c, d – sample Brz40/1, fine flakes of biotite (red arrow), organic fragments (green arrow) and opaque components, c-PPL, d-XPL; e – sample Brz40/8, a fragment of sedimentary rock with thermally altered glauconite (green arrow), PPL; f – sample Brz40/9, grains of thermally altered glauconite (green arrows), fragment of chalcedony (Ch) and crumbs of grog, PPL; photos in Plane Polarized Light (PPL) or Crossed Polarized Light (XPL)

other ceramic fabrics. However, the provenance of the raw material of this fabric is difficult to determine (Fig. 5: g, h).

4.4. Technology – intentional admixtures (tempers), ceramic fabrics

A few intentional admixtures were identified within ceramic fabrics, namely organic material, grog, and sand (Fig. 6: a, b, c). Nevertheless, the occurrence of sand within the pottery does not necessarily mean that it was added to the clay substance intentionally. In

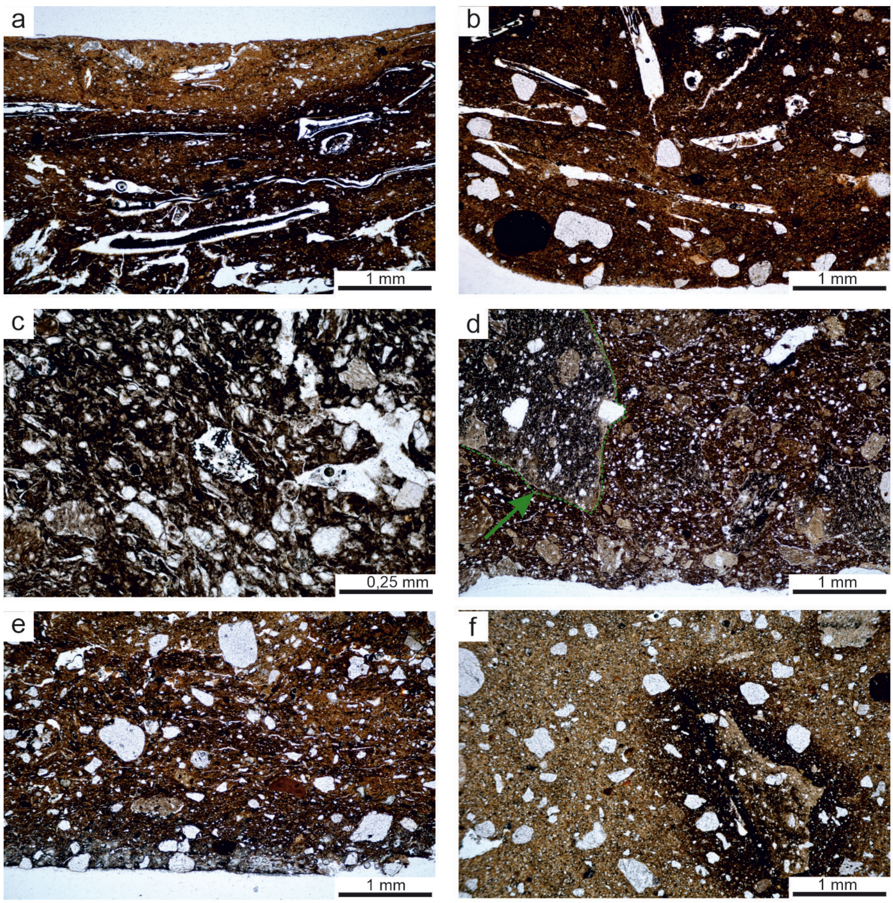

Fig. 6. Photomicrographs of thin sections; a – sample Brz40/3, numerous plant fragments in fine-grained fabric; b – sample Brz40/15, planar voids in ceramic body; c – sample Tar14-15/39, fragments of grog in ceramic paste, plant fragment (in the middle); d – sample Tar14-15/8, fragment with an older generation of grog (arrow); e – sample Tar16/10, sand admixture; f – sample Tar16/5, sand and grog admixture; all photos in Plane Polarized Light (PPL)

this respect, a gathering of locally available raw materials turned out to be useful. A lack of sand within sampled clay samples allows concluding that the sand was added intentionally.

Organic material is usually represented by tiny, elongated fragments of plants. Sometimes the cell structure of these tissues is visible. In the microscopic image, they are black in colour and opaque. Within the zones of vessel walls that became oxidised during the firing process, such fragments preserve extremely rarely. They are more commonly encountered within the core of the vessel wall, where the firing process induced reducing conditions. The analyses revealed that an organic admixture was most frequently used at

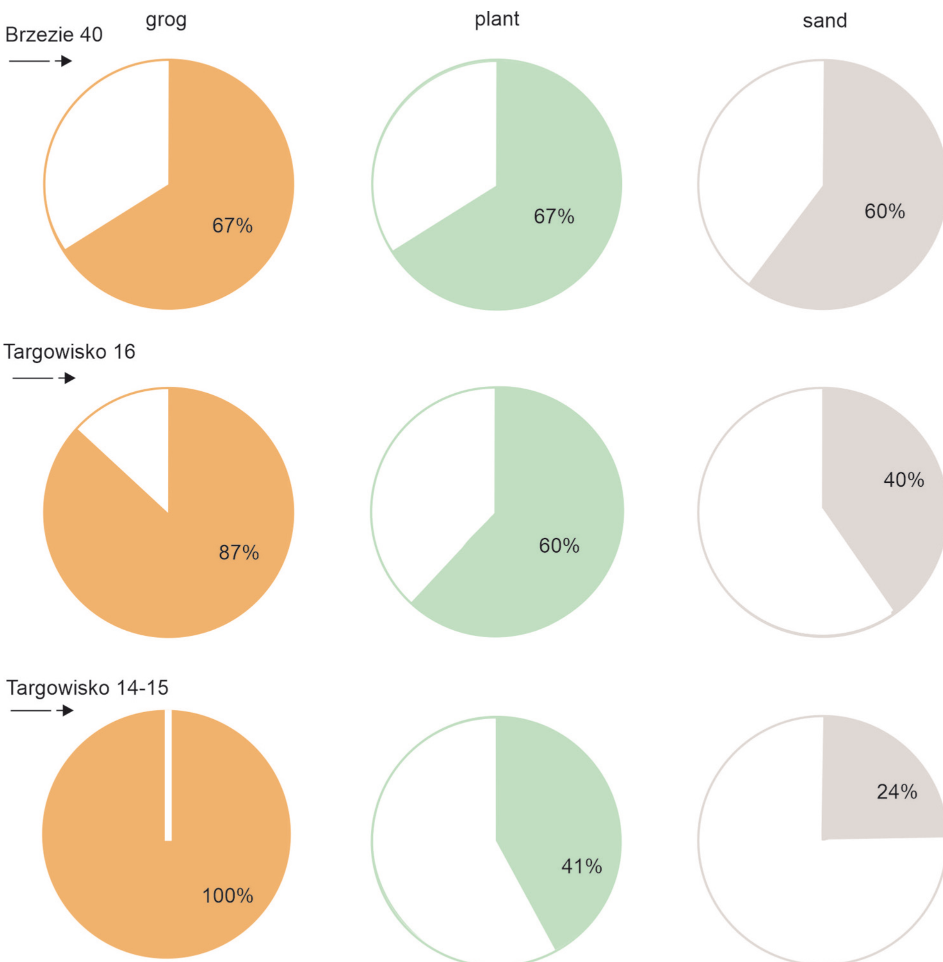

Fig. 7. Percentage share of samples with grog, plant, and sand admixture; sites Brzezie 40 (n=15), Targowisko 16 (n=15), and Targowisko 14-15 (n=17)

Table 4. Percent of ceramic fabrics with particular admixtures: plant, grog, and sand

Site	Type of the vessels	Samples with grog temper	Samples without grog temper	Total	Samples with organic fragments	Samples without organic fragments	Total	Samples with sand admixture	Samples without sand admixture	Total
Brzezie 40	**all type of vessels**	**67**	33	100	**67**	33	100	**60**	40	100
n=15	fine	50	50	100	33	67	100	27	73	100
	medium	67	33	100	100	0	100	13	87	100
	coarse	83	17	100	83	17	100	20	80	100
Targowisko 16	**all type of vessels**	**87**	13	100	**60**	40	100	40	60	100
n=15	fine	78	22	100	67	33	100	27	73	100
	medium	0	100	100	0	100	100	0	100	100
	coarse	100	0	100	50	50	100	13	87	100
Targowisko 14-15	**all type of vessels**	**100**	0	100	**41**	59	100	**24**	76	100
n=17	fine	100	0	100	63	37	100	18	82	100
	coarse	100	0	100	22	78	100	6	94	100

the site of Brzezie 40 (Fig. 7; Table 4). It was recorded within 67% of all fragments under investigation. This admixture was most commonly encountered in thick-walled vessels (in 83% of all thick-walled fragments). With regard to the materials from Targowisko 16, it was less frequent, recorded in 60% of pottery specimens. This indicates a certain tendency to use organic admixture in ceramic fabrics for the production of thin- and medium-walled vessels, with a slight predominance of the former. This type of temper was the rarest in the pottery gathered at Targowisko 14-15 (MC). It was recorded in 41% of all fragments, mostly within ceramic fabrics of thin-walled vessels. At this point, it should be stressed that in their microscopic image, these fragments look slightly different than the "typical" organic fragments encountered in LBK ceramic fabrics; however, in this particular case, specialised analyses of organic remains have not been performed (Fig. 6, c).

The most commonly encountered admixture in the investigated materials was grog. Fragments of older crushed pottery used as a temper have various dimensions (*ca.* 0.1-2.0 mm) and colours. They often resemble the ceramic fabrics to which they were added. The investigations revealed a certain variability in the addition of grog to ceramic vessels at the three sites under studies. With regard to the pottery gathered from Brzezie 40, it was identified within 67% of all fragments. Most of these instances of grog addition occurred within ceramic fabrics used for the production of thick-walled vessels. At the site Targowisko 16, grog was encountered in all thick-walled specimens, which made up 87% of all vessels, but was not found in any other specimens. Whereas, at the site Targowisko 14-15 this type of temper occurred in all ceramic fragments, with no exception.

The sand admixture was recorded within many samples (*ca.* 20) and is represented by rounded grains with a diameter of *ca.* 0.1-0.6 mm. The admixture of sand occurs within 40% of all investigated fragments. With regard to this type of admixture, certain variability is also present. Within the materials from Brzezie 40, sand is the most frequent admixture, encountered in 60% of all fragments. With regard to the series from Targowisko 16, it occurred within 40% of pottery fragments. The smallest number of ceramic fabrics con-

Table 5. Short description of ceramic fabrics, LBK, south-eastern Poland

Fabric type	Description
Fabric type I	heavy clay, fine grained, moderately sorted, admixture of organic fragments
Fabric type II	silty clay, fine grained, well sorted, admixture of organic fragments
Fabric type III	heavy to silty clay, coarse grained, poorly sorted, admixture of organic fragments
Fabric type IV	heavy clay, fine grained, admixture of sedimentary rocks and organic fragments
Fabric type V	heavy to silty clay, coarse grained, poorly sorted, admixture of sand and organic fragments
Fabric type VI	heavy to silty clay, admixture of grog
Fabric type VII	heavy to silty clay, admixture of grog and sand

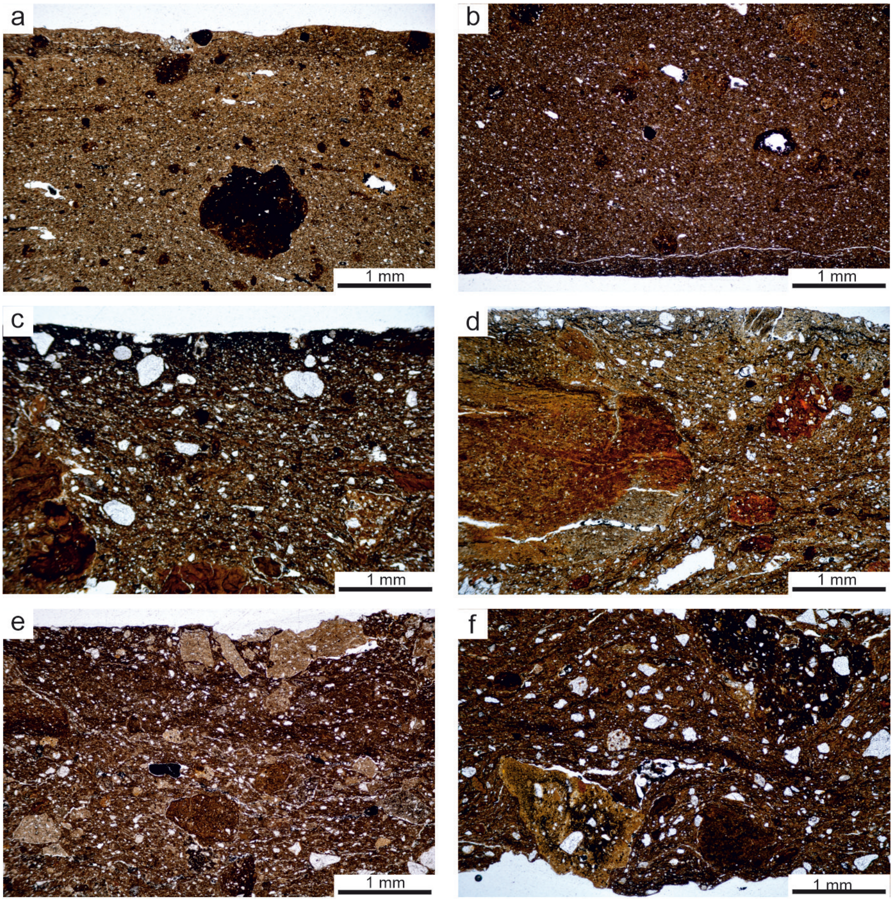

Fig. 8. Ceramic fabric type, photomicrographs of thin sections; a – fabric type I, very fine-grained, heavy clay, without admixture (sample Tar16/3); b – fabric type II, silty clay, fine-grained, very well sorted (sample Tar16/6); c – fabric type III, admixture of sand (sample Brz40/11); d – fabric type IV, admixture of sedimentary rock (sample Brz40/5); e – fabric type VI, admixture of grog (sample Tar14-15/8); f – fabric type VII, admixture of sand and grog (sample Tar16/11); all photos in Plane Polarized Light (PPL)

taining sand was recorded at Targowisko 14-15, making up only 24% of specimens there (Fig. 7; Table 4).

Ceramic fabrics are diversified. Based on the proportions of major mineral compounds (including intentional admixtures), a division into several basic ceramic fabrics was proposed (Rauba-Bukowska *et al*. 2007; Rauba-Bukowska and Czekaj-Zastawny 2020). Each fragment of pottery under analysis was classified to a respective type of ceramic fabric (Table 5; Fig. 8).

4.5. Technology – firing

Most of the vessels were fired in reducing conditions, with a small amount of air-intake at the end of firing or during the cooling process. A great majority of the pottery was fired at a temperature of *ca*. 700-750°C, sporadically exceeding 800-850°C. Conditions and approximate firing temperatures were determined for the investigated fragments of vessels, namely those from which thin sections were taken.

With regard to the material from Brzezie 40, thin- and thick-walled vessels bear traces of reduction firing, with a small amount of air-intake (redox). Only three vessels were fired in a reducing atmosphere. None of the analysed vessels from Brzezie 40 were fired in oxidising conditions.

At the site of Targowisko 16, a great majority of thin- and thick-walled vessels were fired in reducing conditions, with a small amount of air-intake at the end of firing and during the cooling process. Only one thin-walled vessel was fired in reducing conditions; another two thin-walled vessels were produced using the oxidising firing method.

On the other hand thin- and thick-walled vessels from Targowisko 14-15 were fired in reducing conditions, with a small amount of air-intake at the end of firing and during the cooling process. The reducing firing method was applied in the production of four vessels (three thin-walled and one thick-walled). One thick-walled vessel was fired in oxidising conditions.

Based on the above-mentioned observations, a conclusion was formed that the differences in firing technology between the ceramic materials gathered at the three investigated sites were insignificant. Additionally, no transformation in the firing structure of thin- and thick-walled vessels was noted. A great majority of the pottery bears traces of reduction firing with a small amount of air-intake. This means that even if the firing technology had changed, the change was not significant enough to leave any distinctive traces on the ceramic material.

5. DISCUSSION AND CONCLUSIONS

Ceramic vessels gathered at the three archaeological sites under study were made of locally available ceramic raw materials. At the site Brzezie 40, clays and silty clays prevailed. However, the characteristics of three pottery fragments found there vary from the “typical” raw material. This concerns fragments Brz40/8 and Brz40/9, which contain such compounds as chunks of clay with glauconite and grains of chalcedony. One could speculate that these vessels actually come from the left bank of the Vistula River, where such ceramic raw materials are more commonly encountered. The provenance of raw material identified in the sample Brzezie 40-1 is more difficult to establish, however, because it contains a more significant amount of fine biotite flakes. Ceramic fabrics used for the pro-

Table 6. Percentage of samples assigned to each fabric type

Fabric type	Brzezie 40 (LBK)	Targowisko 16 (LBK)	Targowisko 14-15 (Malice Culture)	Samples from III phase LBK in SE Poland (302 samples; Rauba-Bukowska and Czekaj-Zastawny 2020)
I		7		13
II	7	20		35
III	20	13		22
IV	20	13		3
V				2
VI	13	20	76	14
VII	40	27	24	11
total	100	100	100	100

duction of vessels from the sites Targowisko 16 and Targowisko 14-15 were made of heavy clays, and in some of them, glauconite grains and remains of plankton with siliceous skeletons (*Diatoms or Radiolaria*?) were identified. This indicates that these clays originally came from the sea floor. Ceramic raw materials sampled from the surroundings of archaeological sites confirm these observations. Raw materials used as ceramic fabrics most closely resemble Miocene clays, *e.g.*, sample BVI, taken from nearby the sites in Brzezie. In spite of some promising physical properties of clays sampled from accumulation terraces of the Raba River (sufficient elasticity and adhesiveness), they seem not to have been used for the production of the analysed pottery. These clays almost entirely lack any mineral (natural) admixture. At the present stage of research, one can only speculate that these clays could have been used for pottery production, but only after mixing them with loess, sand and other admixtures.

The series from Brzezie 40 discussed in this paper is, in terms of raw material and technology, close to the previously investigated materials from the LBK phase III (Table 6, 7). The properties of the ceramic materials from Targowisko 16, on the other hand, bear more resemblance to ceramic fabrics from Targowisko 14-15. That similar technology was applied in pottery production at these two sites is indicated by the following facts. First a similar source of raw material (Miocene clays) and second a strong representation of ceramic fabrics with an admixture of grog.

Application of Miocene clays instead of silty clays (as commonly recorded in materials of the LBK phase III) is the reason for a relatively low contribution of quartz in these samples, accounting for 17% and 19%, respectively, whereas the average quartz percentage within ceramic fabrics known from the LBK phase III amounts to 27% (Table 7).

The second resemblance is manifested by a significant contribution of grog within the ceramic fabrics. For instance, in pottery from Targowisko 16, on average 9%. This value is

Table 7. The average content of quartz and grog in ceramic fabrics; data after Rauba-Bukowska and Czekaj-Zastawny 2020; Rauba-Bukowska *et al.* 2007; 2011; new data highlighted; n – number of analysed samples

Chronology	Ceramic type	Quartz in %	Grog in %
LBK I, n=99	all type of vessels	19,4	0,35
LBK II, n=101	all type of vessels	19,2	0,48
LBK III, n=100	all type of vessels	26,6	4
Malice culture n=40	all type of vessels	26	8
Brzezie 40 (LBK II/III), n=15	all type of vessels	24	4
Targowisko 16 (LBK III), n=15	all type of vessels	17	9
Targowisko 14-15 (Malice culture), n=17	all type of vessels	18	18

considerably greater than the average percentage recorded for the LBK pottery, even in Želiezovce phase in which the admixture of grog appear (Kadrow and Rauba-Bukowska 2016). While ceramics from Targowisko 14-15 are similarity to those from Targowisko 16, the technology of pottery production definitely varies between the two – in MC grog is a prevailing and organic temper is only marginal and a few plant fragments look different than in the LBK. This technology corresponds well with previous findings and results of studies on this cultural unit (Kozłowski 1996; Rauba-Bukowska *et al.* 2007; Rauba-Bukowska 2011; Rauba-Bukowska 2014a).

6. CONCLUSION

The major indicator of pottery of the late LBK phases is the occurrence of grog admixture and the definitely rarer application of plant temper, as well as a decrease in the contribution of ceramic fabrics containing sand. Neither the manner nor the temperature of firing vary. With regard to the three ceramic series discussed in this paper, the following traits can be listed:

– at Brzezie 40, phase II/III of the LBK, grog and organic material occur mainly within ceramic fabrics used for the production of medium- and thick-walled vessels;

– at Targowisko 16, phase III of the LBK, grog is present in all of the ceramic fabrics used for the production of thick-walled vessels, while organic material was identified mostly in thin-walled specimens;

– at Targowisko 14-15 (MC), grog is present in all of the types of pottery, while organic material occurs mainly within the thin-walled vessels;

– the occurrence of sand admixture decreases from 60% in vessels from Brzezie 40 to 25% in the MC pottery;

– organic fragments identified within the ceramic fabrics of the MC vessels reveal a different structure/morphology; therefore, based on the general microscopic image, they vary from those encountered within the LBK ceramic fabrics.

The LBK series of pottery described in this paper revealed a significant predominance of ceramic fabrics containing grog when compared with the series of previously investigated materials (Table 5, 6; Rauba-Bukowska and Czekaj-Zastawny 2020). In general, in the assemblages of the LBK phase III, ceramic fabrics with grog admixture constituted *ca.* 25% of all specimens, while in Brzezie 40, these fabrics accounted for 67%, and in Targowisko, 16-87%. This surplus, however, could be due to local preferences. Ceramics of the MC show grog-tempered ceramic pastes. Similar results are seen at the Rzeszów-Piastów site. In subsequent stylistic phases of LBK, there is a visible, gradual increase in the technology without admixture (technological group A – after Kadrow 1990) and with grog additives (technological group C – after Kadrow 1990). On the other hand, the ceramics of the MC present the grog technology, and the organic admixture is identified to a negligible extent (Kadrow 1990, 29).

The mechanism of using grog temper can be compared by analogy to the use of an organic admixture, which has been discussed in detail by Kreiter Á., Pető and P. Pánczél: "It has been shown above that there are extensive ceramic technological similarities between Neolithic communities across a large geographical area, and, above all, vegetal tempering seems to be the most consistent pattern in Neolithic ceramic production" (Kreiter *et al.* 2013). Michela Spataro mentions vegetal material in the context of the Starčevo-Criş culture as a main characteristic element of this culture, which distinguishes it from other cultural groups (Spataro 2008; 2019). The process of decreasing the addition of the organic admixture begins in the Middle Neolithic, and vegetal admixture disappeared in the Late Neolithic (Kreiter 2010; Kreiter *et al.* 2011; 2013). Observations confirm this at many Hungarian sites, where the limited use of an organic admixture has been noted, *e.g.*, in ceramics of the Želiezovce group at the site of Szécsény-Ültetés (Kreiter *et al.* 2013). This corresponds well with the results from Polish sites (Rauba-Bukowska and Czekaj-Zastawny 2020). Kreiter and colleagues write: ".. it is suggested that the cross-cultural utilisation of chaff temper cannot only be explained by its ready availability in a particular period of the year, but its social significance must also be sought. A vessel tempered with chaff accumulated events through its manufacture, and its production may have strengthened social and production relations between producers, exchange partners." (2013, 140). These conclusions are consistent with the author's observations from the territory of Poland. The main Neolithic admixtures, namely plant and grog additives, have a cultural rather than a technological meaning. In this context, the disappearance of organic admixture and the beginning of grog technology reflects a socio-cultural transformation. Based on the current and previous analyses, it seems that the stylistic/chronological Želiezovce phase may be a "meeting point" of two technological traditions.

According to the petrographic analysis of the LBK in Lesser Poland, an admixture of grog appears in phase III of the LBK. However, we do not know of grog in the Želiezovce group in Slovakia, but the petrographic analysis of several samples from the Bükk culture in Eastern Slovakia shows that in this culture, grog is known as an admixture (Kozłowski *et al.* 2014 (2015); Czekaj-Zastawny *et al.* 2018; Rauba-Bukowska and Czekaj-Zastawny 2020). The Tisza River region shows an extensive relationship with Poland in the time of the ALPC, and this is confirmed by the imports of raw materials – mostly obsidian (*e.g.* Szeliga 2007, 295-297, fig. 1). Simultaneously with this contact, technological innovation (*e.g.* the usage of grog) approached Lesser Poland (Kozłowski *et al.* 2015; Kadrow and Rauba-Bukowska 2016; Czekaj-Zastawny *et al.* 2017; Rauba-Bukowska and Czekaj-Zastawny 2020). This is a hypothesis which has been studied lately. As there is no data, *e.g.*, from the Slovakian Želiezovce group, the ALPC is our primary suspect, which could have spread grog-tempered ceramics to Lesser Poland in the late LBK. To strengthen or reject this hypothesis, however, requires further studies.

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