The selection of ceramic raw material: convenience or a technological idea? A case study of the Danubian cultures north of the Carpathians

Výběr keramických surovin: příhodnost nebo technologický plán? Případová studie podunajských kultur severně od Karpat

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This paper reconstructs the rules governing the selection of ceramic raw material and considers certain technological aspects of the production of ceramic vessels in some Danubian cultures around the Carpathians in the Neolithic. The analysis encompassed more than 500 samples of ceramics produced by various cultural units across different chronological horizons. The results of the analysis are used to verify several hypotheses concerning the relationships and the mechanisms of cultural change in the Carpathian region. The most important questions include: (1) evolution of the LBK ceramics, (2) influence of the ALPC on the evolution of the LBK pottery in Małopolska, (3) technology of the LBK ceramics east of the Carpathians, (4) culture change at the turn of the LBK and the MC in Małopolska and (5) culture change at the turn of the MC and the L-VC in the same region. The suitability of the pottery technological analysis to solve some prehistoric problems was confirmed.

LBK – ALPC – trans-Carpathian contacts – pottery – clay raw materials – technological analysis

Článek rekonstruuje pravidla ovládající výběr keramických surovin a zvažuje určité technologické aspekty výroby keramických nádob v některých podunajských kulturách neolitu v oblasti Karpat. Analyzováno bylo více než 500 keramických vzorků vytvořených různými kulturními jednotkami různých chronologických horizontů. Výsledky analýzy slouží k ověření několika hypotéz týkajících se souvislostí a mechanismů kulturní změny v karpatské oblasti. Mezi nejdůležitější otázky patří: (1) vývoj LBK keramiky, (2) vliv ALPC na vývoj LBK keramiky v Malopolsku, (3) technologie LBK keramiky východně od Karpat, (4) kulturní změna na přechodu mezi LBK a MC v Malopolsku, (5) kulturní změna na přechodu mezi MC a L-VC v téže oblasti. Výsledky potvrzují vhodnost analýzy technologie keramiky pro objasnění některých otázek pravěku.

LBK – ALPC – trans-karpatské kontakty – keramika – keramické suroviny – technologická analýza

Introduction

The aim of this paper is to reconstruct the rules governing the selection of ceramic raw material and to consider certain technological aspects of the production of ceramic vessels by the Linear Pottery culture (LBK) and some younger Danubian cultures north of the Carpathians. The analysis encompassed more than 500 samples of ceramics produced by various cultural units in various chronological periods (*Rauba-Bukowska et al. 2007*; *Rauba-Bukowska 2011*; *2014a*; *2014b*; *Czekaj-Zastawny – Rauba-Bukowska 2013*; *2014*; *Kozłowski et al. 2014*; *Czekaj-Zastawny et al. 2017*). In this paper we take also into consideration new samples: the Starčevo-Criş culture in its final phase; the LBK in phases I–III; the Alföld Linear

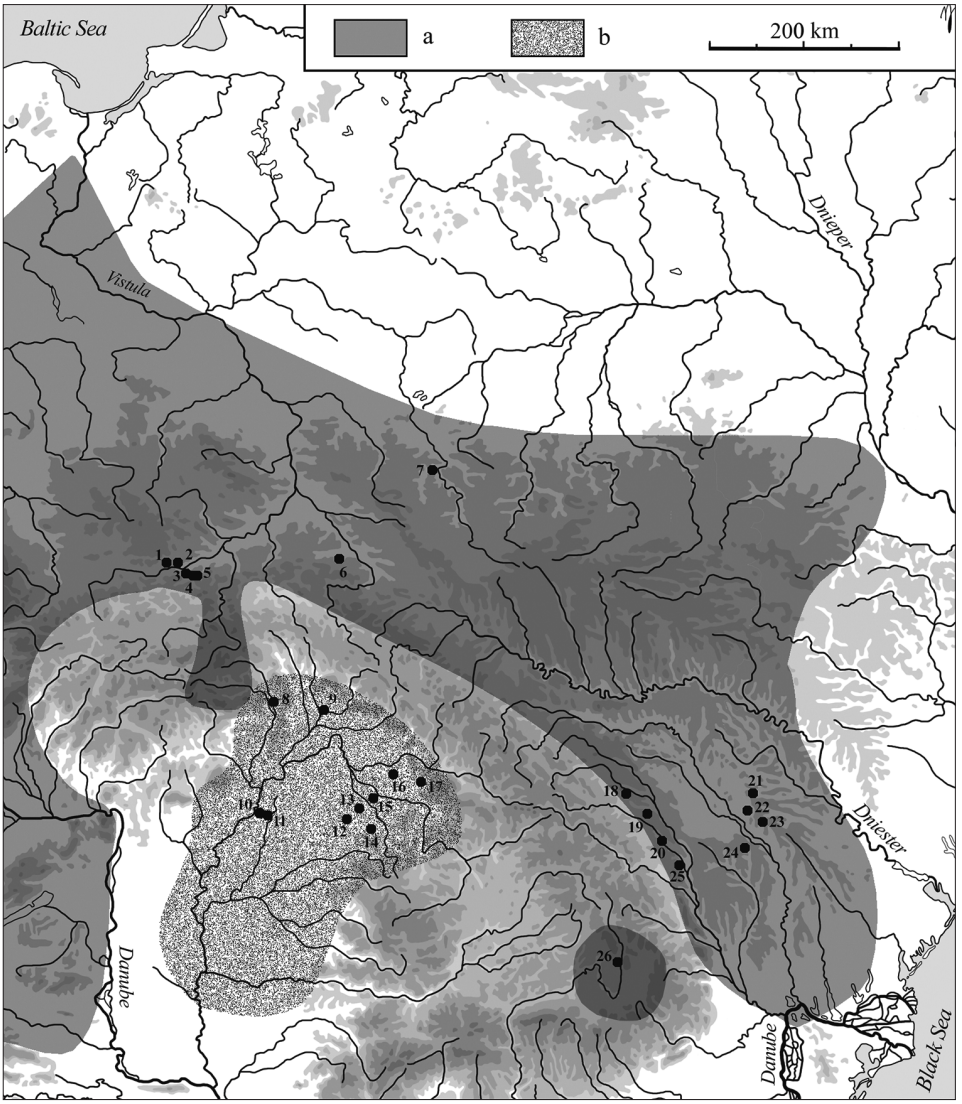

Fig. 1. Locations of the sites with ceramic material analysed in the article; 1 – Modlnica 5; 2 – Kraków – Nowa Huta – Mogiła 62; 3 – Zagórze 2; 4 – Brzezie 17; 5 – Targowisko 10–11; 6 – Rozbórz 42; 7 – Świerszczów 3; 8 – Šarišské Michaľany; 9 – Zemplínske Kopčany; 10 – Polgár-Csőszhalom; 11 – Polgár-Piocasi; 12 – Pişcolt; 13 – Căpleni; 14 – Tăşnad; 15 – Homorodul; 16 – Halmeu; 17 – Călineşti-Oaş; 18 – Mihoveni; 19 – Preuteşti; 20 – Târpeşti; 21 – Chişcăreni; 22 – Bumbăta; 23 – Găureni; 24 – Isaiia; 25 – Traian Dealul, dept. Neamţ; 26 – Olteni; a – LBK area; b – ALPC area.

Pottery culture (ALPC) in its younger phase (including Pişcolt group); the post-ALPC Iclod group; the Malice (MC) and the Lublin-Volhynia (L-VC) cultures (*fig. 1*; *tab. 1*). The units evolved for over 1500 years, from c. 5500 BC to c. 4000/3800 BC (*fig. 2*).

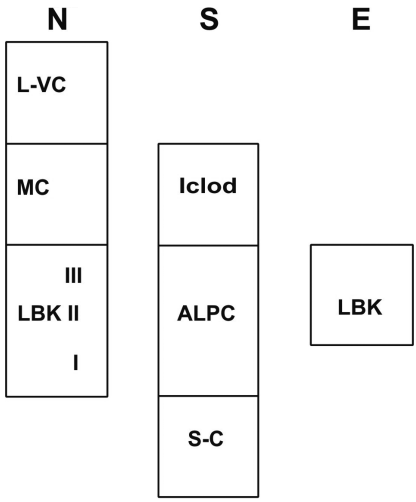

Fig. 2. Chronological synchronization of cultural units referred to in the article; N – areas North of Carpthians, S – areas South of Carpathians, E – areas East of Carpathians; S-C – Starčevo-Criş culture, LBK – Linear Pottery culture, ALPC – Alföld Linear Pottery culture, MC – Malice culture, L-VC – Lublin-Volhynian culture, Iclod – Iclod group.

The results of the analysis are used to verify several hypotheses concerning the relationships and the mechanisms of cultural change in the Carpathian region. The most important questions include the continuity or discontinuity of Danube settlement in south-eastern Poland at the turn of the LBK and the MC until the early Eneolithic, as well as the chronology of the LBK east of the arc of the Carpathians, in eastern Romania and in Moldova. The samples, taken from such an extensive area and dated to such a long period, make it possible to reconstruct significant changes in the production of ceramics in the context of crucial sociocultural processes in Małopolska (Little Poland) and the adjacent areas.

The spatial and chronological range of the analysis

The research area has covered large areas of Małopolska, the northern Carpathian Basin, Moldavia east of the arc of the Carpathians, as well as one site in south-eastern Transylvania (*fig. 1: 26*). The ceramic samples have been taken from five sites in western Małopolska: Modlnica 5 and Nowa Huta-Mogiła 62 north of the Vistula, and Zagórze 2, Brzezie 17 and Targowisko 10–11 south of that river (all the sites are located in the Kraków region; *fig. 1: 1–5*), as well as from two sites in eastern Małopolska: Rozbórz 42 and Świerszczów 3 (*fig. 1: 6–7*).

The Slovakian site Zemplínske Kopčany lies in the northern part of the Great Hungarian Plain; Šarišské Michaľany is situated in the hilly Šariš region in the Western Carpathians (*fig. 1: 8–9*), while the Hungarian sites Polgár-Csőszhalom and Polgár-Piocasi are located east of the Tisza in the Great Hungarian Plain (*fig. 1: 10–11*).

The north-western Romanian sites: Pişcolt, Căpleni, Homorodul Vechi, Halmeu, Tăşnad and Călineşti-Oaş (*fig. 1: 12–17*), are located in the farthest north-eastern part of the Great Hungarian Plain. Several Moldavian sites in Romania lie in the Siret basin (Mihoveni, Preuteşti and Târpeşti; *fig. 1: 18–20*); other sites are located in the Prut basin (Isaiia and Traian Dealul; *fig. 24–25*). The sites in the Republic of Moldova lie in the Prut basin (Chişcăreni,

Id.	State	Site	Cultural affiliation	Localisation at the sample
7	Poland	Rozbórz	Linear Pottery culture (LBK)	feature 3233
8	Poland	Rozbórz	Linear Pottery culture (LBK)	feature 3233
9	Poland	Rozbórz	Linear Pottery culture (LBK)	feature 2980
10	Poland	Rozbórz	Linear Pottery culture (LBK)	feature 2980
11	Poland	Rozbórz	Malice culture (MC)	feature 500
12	Poland	Rozbórz	Linear Pottery culture (LBK)	feature 2980
13	Poland	Rozbórz	Linear Pottery culture (LBK)	feature 3233
14	Poland	Rozbórz	Malice culture (MC)	feature 500
15	Poland	Rozbórz	Malice culture (MC)	feature 371
16	Poland	Rozbórz	Linear Pottery culture (LBK)	feature 2980
41	Poland	Zagórze	Linear Pottery culture (LBK)	feature 7073
42	Poland	Zagórze	Linear Pottery culture (LBK)	feature 7073
43	Poland	Zagórze	Linear Pottery culture (LBK)	feature 7073
44	Poland	Zagórze	Linear Pottery culture (LBK)	feature 7073
45	Poland	Rozbórz	Linear Pottery culture (LBK)	feature 111
46	Poland	Rozbórz	Linear Pottery culture (LBK)	feature 111
47	Poland	Rozbórz	Linear Pottery culture (LBK)	feature 111
48	Poland	Rozbórz	Linear Pottery culture (LBK)	feature 111
49	Poland	Rozbórz	Linear Pottery culture (LBK)	feature 111
50	Poland	Rozbórz	Linear Pottery culture (LBK)	feature 500
51	Poland	Rozbórz	Linear Pottery culture (LBK)	feature 500
52	Poland	Rozbórz	Linear Pottery culture (LBK)	feature 111
53	Poland	Rozbórz	Malice culture (MC)	feature 500
54	Poland	Rozbórz	Malice culture (MC)	feature 111
55	Poland	Rozbórz	Malice culture (MC)	feature 111
56	Poland	Rozbórz	Malice culture (MC)	feature 111
57	Poland	Rozbórz	Malice culture (MC)	feature 111
58	Poland	Rozbórz	Linear Pottery culture (LBK)	feature 500
59	Poland	Rozbórz	Malice culture (MC)	feature 111
60	Poland	Świerszczów	Lublin-Volhynia culture (L-VC)	feature 143
61	Poland	Świerszczów	Lublin-Volhynia culture (L-VC)	feature 143
62	Poland	Świerszczów	Lublin-Volhynia culture (L-VC)	feature 143
63	Poland	Świerszczów	Lublin-Volhynia culture (L-VC)	feature 125
64	Poland	Świerszczów	Lublin-Volhynia culture (L-VC)	feature 125
65	Poland	Świerszczów	Lublin-Volhynia culture (L-VC)	feature 143
66	Poland	Świerszczów	Lublin-Volhynia culture (L-VC)	feature 6
67	Poland	Świerszczów	Lublin-Volhynia culture (L-VC)	feature 141/A
68	Poland	Świerszczów	Lublin-Volhynia culture (L-VC)	feature 143
69	Poland	Świerszczów	Lublin-Volhynia culture (L-VC)	feature 143
70	Romania	Isaiia, jud.Iaşi	Linear Pottery culture (LBK)	*
71	Romania	Isaiia, jud.Iaşi	Linear Pottery culture (LBK)	*
72	Romania	Isaiia, jud.Iaşi	Linear Pottery culture (LBK)	*
73	Romania	Isaiia, jud.Iaşi	Linear Pottery culture (LBK)	*
74	Romania	Isaiia, jud.Iaşi	Linear Pottery culture (LBK)	*
75	Romania	Olteni, jud. Covasna	Linear Pottery culture (LBK)	*
76	Romania	Olteni, jud. Covasna	Linear Pottery culture (LBK)	*
77	Romania	Olteni, jud. Covasna	Linear Pottery culture (LBK)	*
78	Romania	Olteni, jud. Covasna	Linear Pottery culture (LBK)	*
79	Romania	Mihoveni, jud. Suceava	Linear Pottery culture (LBK)	*
80	Romania	Mihoveni, jud. Suceava	Linear Pottery culture (LBK)	*
81	Romania	Preuteşti-Ciritei, jud. Suceava	Linear Pottery culture (LBK)	*
82	Romania	Preuteşti-Ciritei, jud. Suceava	Linear Pottery culture (LBK)	*
83	Romania	Traian-Dealul Fântânilor, jud. Neamţ	Linear Pottery culture (LBK)	*
84	Romania	Traian-Dealul Fântânilor, jud. Neamţ	Linear Pottery culture (LBK)	*
85	Romania	Traian-Dealul Fântânilor, jud. Neamţ	Linear Pottery culture (LBK)	*
86	Romania	Traian-Dealul Fântânilor, jud. Neamţ	Linear Pottery culture (LBK)	*
87	Romania	Traian-Dealul Fântânilor, jud. Neamţ	Linear Pottery culture (LBK)	*
88	Romania	Târpeşti, jud. Neamţ	Linear Pottery culture (LBK)	*
89	Romania	Târpeşti, jud. Neamţ	Linear Pottery culture (LBK)	*
90	Romania	Târpeşti, jud. Neamţ	Linear Pottery culture (LBK)	*
91	Romania	Târpeşti, jud. Neamţ	Linear Pottery culture (LBK)	*
92	Romania	Târpeşti, jud. Neamţ	Linear Pottery culture (LBK)	*

93	Romania	Tăşnad-Sere 2014	Starčevo-Criş culture	Pit 1- Analystra Hotel section, 2014
94	Romania	Tăşnad-Sere 2014	Starčevo-Criş culture	Pit 1- Analystra Hotel section, 2014
95	Romania	Tăşnad-Sere 2014	Starčevo-Criş culture	Pit 1- Analystra Hotel section, 2014
96	Romania	Tăşnad-Sere 2014	Starčevo-Criş culture	Pit 1- Analystra Hotel section, 2014
97	Romania	Tăşnad-Sere 2014	Starčevo-Criş culture	Pit 1- Analystra Hotel section, 2014
98	Romania	Călineşti-Oaş 2001	Starčevo-Criş culture	Dâmbul Sfinetei Marii, S I, C 1 – 0,40–0,5 m, 2001
99	Romania	Călineşti-Oaş 2001	Starčevo-Criş culture	Dâmbul Sfinetei Marii, S I, C 1 – 0,40–0,5 m, 2001
100	Romania	Călineşti-Oaş 2001	Starčevo-Criş culture	Dâmbul Sfinetei Marii, S I, C 1 – 0,40–0,5 m, 2001
101	Romania	Călineşti-Oaş 2001	Starčevo-Criş culture	Dâmbul Sfinetei Marii, S I, C 1 – 0,40–0,5 m, 2001
102	Romania	Călineşti-Oaş 2001	Starčevo-Criş culture	Dâmbul Sfinetei Marii, S I, C 1 – 0,40–0,5 m, 2001
104	Romania	Homorodul	Starčevo-Criş culture	Cx. 1 (Pit 1)
105	Romania	Homorodul	Starčevo-Criş culture	Cx. 1 (Pit 1)
106	Romania	Homorodul	Starčevo-Criş culture	Cx. 1 (Pit 1)
107	Romania	Homorodul	Starčevo-Criş culture	Cx. 1 (Pit 1)
108	Romania	Halmeu-Vamă	Alföld Linear Pottery culture (ALPC) – Pişcolt group	Cx 46
109	Romania	Halmeu-Vamă	Alföld Linear Pottery culture (ALPC) – Pişcolt group	Cx 46
110	Romania	Halmeu-Vamă	Alföld Linear Pottery culture (ALPC) – Pişcolt group	Cx 46
112	Romania	Halmeu-Vamă	Alföld Linear Pottery culture (ALPC) – Pişcolt group	Cx 46
113	Romania	Halmeu-Vamă	post Alföld Linear Pottery culture (ALPC) – Iclod group	Cx. 5
114	Romania	Halmeu-Vamă	post Alföld Linear Pottery culture (ALPC) – Iclod group	Cx. 5
115	Romania	Halmeu-Vamă	post Alföld Linear Pottery culture (ALPC) – Iclod group	Cx. 5
116	Romania	Halmeu-Vamă	post Alföld Linear Pottery culture (ALPC) – Iclod group	Cx. 5
117	Romania	Halmeu-Vamă	post Alföld Linear Pottery culture (ALPC) – Iclod group	Cx. 5
119	Romania	Pişcolt-Lutărie	Alföld Linear Pottery culture (ALPC) – Pişcolt group	G1
120	Romania	Pişcolt-Lutărie	Alföld Linear Pottery culture (ALPC) – Pişcolt group	G1
121	Romania	Pişcolt-Lutărie	Alföld Linear Pottery culture (ALPC) – Pişcolt group	G1
122	Romania	Pişcolt-Lutărie	Alföld Linear Pottery culture (ALPC) – Pişcolt group	G1
123	Romania	Pişcolt-Lutărie	Alföld Linear Pottery culture (ALPC) – Pişcolt group	G1
124	Romania	Pişcolt-Lutărie	Alföld Linear Pottery culture (ALPC) – Pişcolt group	G1
125	Romania	Pişcolt-Lutărie	Alföld Linear Pottery culture (ALPC) – Pişcolt group	G1
126	Romania	Pişcolt-Lutărie	Alföld Linear Pottery culture (ALPC) – Pişcolt group	G1
127	Romania	Pişcolt-Lutărie	Alföld Linear Pottery culture (ALPC) – Pişcolt group	G1
128	Romania	Pişcolt-Lutărie	Alföld Linear Pottery culture (ALPC) – Pişcolt group	*
129	Romania	Pişcolt-Lutărie	Alföld Linear Pottery culture (ALPC) – Pişcolt group	*
130	Romania	Pişcolt-Lutărie	Alföld Linear Pottery culture (ALPC) – Pişcolt group	*
131	Romania	Pişcolt-Lutărie	Alföld Linear Pottery culture (ALPC) – Pişcolt group	*
132	Romania	Pişcolt-Lutărie	Alföld Linear Pottery culture (ALPC) – Pişcolt group	*
134	Romania	Pişcolt-Lutărie	Alföld Linear Pottery culture (ALPC) – Pişcolt group	G 8/9
135	Romania	Pişcolt-Lutărie	Alföld Linear Pottery culture (ALPC) – Pişcolt group	G 8/9
136	Romania	Pişcolt-Lutărie	Alföld Linear Pottery culture (ALPC) – Pişcolt group	G 8/9
137	Romania	Pişcolt-Lutărie	Alföld Linear Pottery culture (ALPC) – Pişcolt group	G 8/9
138	Romania	Căpleni-Drumul	Alföld Linear Pottery culture (ALPC) – Pişcolt group	G1
139	Romania	Căpleni-Drumul	Alföld Linear Pottery culture (ALPC) – Pişcolt group	G1
140	Romania	Căpleni-Drumul	Alföld Linear Pottery culture (ALPC) – Pişcolt group	G1
141	Romania	Căpleni-Drumul	Alföld Linear Pottery culture (ALPC) – Pişcolt group	G1
142	Romania	Căpleni-Drumul	Alföld Linear Pottery culture (ALPC) – Pişcolt group	G1
143	Moldova	Chişcăreni XIV	Linear Pottery culture (LBK)	*
144	Moldova	Chişcăreni XIV	Linear Pottery culture (LBK)	*
145	Moldova	Bumbăta	Linear Pottery culture (LBK)	sondaj 1
146	Moldova	Bumbăta	Linear Pottery culture (LBK)	sondaj 1
147	Moldova	Găureni	Linear Pottery culture (LBK)	sondaj 2
148	Moldova	Găureni	Linear Pottery culture (LBK)	sondaj 2

Tab. 1. List of analyzed samples.

Bumbăta and Găureni; *fig. 1: 21–23*). The only Transylvanian site is situated in Olteni (*fig. 1: 26*).

The samples recovered from the sites in Małopolska represent the LBK (*fig. 1: 2–6*), the MC (*fig. 1: 4–6*) or the L-VC (*fig. 1: 1, 7*). All the samples from Slovakia and Hungary represent the ALPC (*fig. 1: 8–11*), while those from north-western Romania come from the final phase of the Starčevo-Criş culture (*fig. 1: 14, 15, 17*), from Pişcolt, i.e. an element of the ALPC (*fig. 1: 12, 13, 16*), or from the Iclod group (*fig. 1: 16*), representing the post-ALPC horizon of the younger Neolithic. All the other samples from Transylvania (*fig. 1: 26*), eastern Romania (*fig. 1: 18–20, 24–25*) and the Republic of Moldova (*fig. 1: 21–23*) represent the LBK.

The issues considered here, i.e. the changes in the technology of ceramic production, do not require a more precise chronological framework; it is sufficient to propose the general synchronisation of Neolithic cultural phenomena in the areas located north (Małopolska), south (the Great Hungarian Plain) or east (Moldova) of the Carpathians. The analysed assemblages of ceramics have been dated to the long period from the mid-6th millennium to the early 4th millennium BC. They represent several stages in the development of Neolithic pottery in Central and Eastern Europe (*fig. 2*). The proposed chronological schema is based on the findings of researchers who specialise in Neolithic chronology of particular regions (e.g. *Kulczycka-Leciejewiczowa 1979*; *Kadrow 1990*; *2006*; *Kadrow – Zakościelna 2000*; *Pavúk 1980*; *2005*; *Czekaj-Zastawny 2008*; *Dębiec 2015* – Małopolska; *Kalicz – Makkay 1977*; *Kalicz – Raczky 1987*; *Šiška 1989*; *1995*; *Astalos et al. 2013* – the northern part of the Great Hungarian Plain; *Larina 1999*; *2009*; *Dębiec 2012*; *Dębiec – Saile 2015*; *Saile et al. 2016* – Moldova and Ukraine).

The cultural evolution and cultural change around the Carpathians in the Neolithic

The LBK spread to Małopolska and the Western Volhynian Upland in Ukraine in its pre-music-note (I) phase (the Bíňa and the Milanovce phases in south-western Slovakia; cf. *Pavúk 2004*; *Kulczycka-Leciejewiczowa 1983*; *Czekaj-Zastawny 2008*, 16–18; *Dębiec 2015*). The earliest LBK groups migrated to south-eastern Poland from south-western Slovakia and Moravia through the Moravian Gate. There are nearly 30 sites representing the older LBK phase in Małopolska (*Kozłowski et al. 2014*, 39).

In the music-note phase (II), the LBK population gradually increased, reaching its peak in the Želiezovce phase (III). During the LBK evolution, the inner rhythm of cultural change was the same throughout almost the whole of Małopolska and in south-western Slovakia. The course of its development ran differently, however, in the Dniester basin (Ukraine and Moldova) and in the areas on the Prut and the Seret rivers (Moldova), where assemblages from the music-note (II) phase have been the only LBK pottery recorded and where no ceramic materials representing the Želiezovce phase (III) have been found to date. It is difficult to determine, therefore, whether LBK settlement lasted there solely to the end of phase II (e.g. *Larina 1999*) or longer, to the end of phase III, but without adapting the Želiezovce style used in the ornamentation of ceramics in south-western Slovakia, although the influences may have come through Małopolska (e.g. *Kozłowski 1981*; *Dębiec 2012*).

Some archaeologists argue that there was no cultural or settlement continuation of the LBK in the MC. They believe that contacts between Małopolska and the borderland between east Slovakia and north-eastern Hungary ceased abruptly with the end of the LBK and the Bükk culture (*Kozłowski et al. 2014*, 41). Post-Linear settlers, i.e. Malice communities, came presumably from the Carpathian Basin across the mountains (*Kaczanowska 1990*; *Kamieńska – Kozłowski 1990*; *Kozłowski 2004*, 11).

Other researchers question that explanation. They prefer the model of a gradual but profound process of change within the LBK community in its late (III) phase (*Kulczycka-Leciejewiczowa 2004*, 21). The change, they maintain, brought about the transformation of the LBK into the MC (*Kadrow 2005*, 26–27).

The origin of the L-VC remains unclear. The culture was still Neolithic in its oldest phase and then it developed into a fully Eneolithic unit under the Polgár influence (*Zakościelna 2010*, 218–233). Some researchers point to its local character and to its relationship with the MC (*Kadrow – Zakościelna 2000*, 245–249). Others emphasise the forming impact of the communities inhabiting the Carpathian Basin (e.g. *Kozłowski 1989*, 192–195).

The ALPC originated and evolved initially in the middle and upper Tisza basin. It resulted from the expansion of the Starčevo-Criş culture to the area. The Méhtelek and the Szatmar groups functioned as transitional units between the Starčevo-Criş culture and the developed ALPC (*Kozłowski et al. 2014*, 42–43).

From the outset, ALPC ceramics showed regional differentiation and thus diverging from the relatively uniform ceramics of the LBK. Both cultural complexes differed considerably in their settlement patterns and dwelling constructions.

The Tisza culture (TC) in its earliest phase developed on the basis of late ALPC groups (*Kalicz – Raczky 1987*, 30). Its formation in the borderland between Hungary, Romania and Carpathian Ruthenia was accompanied by the development of similar cultural units, e.g. the Iclod group. Romanian researchers argue that the Starčevo-Criş culture lasted for a long period in that area, being partly contemporaneous with the ALPC (cf. *Astalos et al. 2013*).

The methods of analysing the samples

Nearly 500 samples of ceramics and clay ascribed to the LBK (the earlier Neolithic), the MC (the later Neolithic) and the L-VC (early Eneolithic) from Małopolska, including imports and imitations of the ALPC, have been collected in recent years. The technological analysis of the ceramics from south-eastern Poland, the northern Carpathian Basin and the areas east of the Carpathians has centred on the mineralogical and petrographic composition and component quantity ratios.

Thin sections taken from the ceramic fragments have been examined with a Nikon Eclipse LV100N POL polarized light microscope. Next, quantitative petrographic analysis (point counting; see *Quinn 2013* with references within) was used to determine the percentage of individual components: clay minerals, quartz, alkali feldspars, plagioclases, muscovite, biotite, carbonates, grains of sedimentary, igneous or metamorphic rocks, grog fragments and organic material (*tab. 2*). The research also involved the schematic petrographic description of individual thin sections.

lp.	site	clay minerals	grains < 0,02 mm	quartz (>0,02 mm)	flint/chalcedony	K-feldspars	plagioclases	fragments of sedimentary rocks	fragments of igneous rocks	fragments of metamorphic rocks	muscovite	biotite	opaque minerals	iron oxides and hydroxides	grog	clasts of unmixed clay	organic fragments	voids	carbonates	amphiboles	others
7	Rozbórz	53.8	8.9	23.4	0.9	4.5	0.3		0.3	0.1	1.5	0	0.3	1.5		2.7		1.8			
8	Rozbórz	48.6	15.4	7.7	0	1.9	0				11.2	0.1	0.4	4.6	0.1		0.8	7.3			1.9
9	Rozbórz	56	17.8	7.4	0	1.4					6.9	1.1	0.3	2.6				6.5			
10	Rozbórz	49.4	22.1	21.3	0.1	2.6	0.1				1.8	0.3	0	0				2.3			
11	Rozbórz	66.8	18.9	3.4		0.6					2.7	0.3	0.6	4				2.7			
12	Rozbórz	55.2	14.8	15.6	0.4	2.3					3.1		3.9	3.5		1.2		0			
13	Rozbórz	56.5	7.3	21.1	0.1	5.8	0.1			0.9	0.9		0	1.8		2.9		2.6			
14	Rozbórz	43.4	19.9	11.6		3.7	0.4				9.7	7.9	1.5	0		0.4		1.5			
15	Rozbórz	59.6	7.8	3.4	0.1	0.6					0.6		0	3.4	8.9	6.7		8.9			
16	Rozbórz	53	20	8.4	1.8	1.1					1.1		0	0.4		5.4	2.6	6.2			
41	Zagórze	62.7	9.4	6.7		0.6					0.9		1.5	1.8		2.6	5.9	7.6			0.3
42	Zagórze	57	12	9.5		1.4		0.8			3.3					1.1	9.6	5			0.3
43	Zagórze	51.9	7	30.5		0.8								2.9		0.5	0.5	5.3			0.6
44	Zagórze	55.6	11	10.2							1.9			0.3		2.8	6.6	11			0.6
45	Rozbórz	54.7	17.3	14.5	0.3	1.9		0.1			2.2		1.4	3.1		0.6	1.1	2.8			
46	Rozbórz	70.1	14.8	3.7		0					6.4	1.3	0.3	0.7		0.7	0.3	1.7			
47	Rozbórz	65	14.1	9.9	0.1	1.7					1.4		1.9	1.7		0.9	0	3.3			
48	Rozbórz	51.8	14	20.8	0.1	8.4				0.5	0.8		0	0.8		0	0.3	2.5			
49	Rozbórz	39	35	11		1.2					4.5	1.8	0.6	0.3		4.2	0.3	0.9			1.2
50	Rozbórz	55.6	5.3	17.3		3.6			0.8		0.3		0.3	0.6		0	8.9	7.3			
51	Rozbórz	52.8	12.3	18.8	0.1	2.7				0.3	2.1	0.3	0.6	2.4		5.2	0	2.4			
52	Rozbórz	54.1	3.5	11.2		1.9					0.3		0	4.5		16.8	2.1	5.6			
53	Rozbórz	53.9	23.3	8.9		2.9	0.3				6.9	0.3	0	0.3		0.6	0.3	2.3			
54	Rozbórz	58.6	10.5	2.8		0.7			0.3	0.7	2.8		0.3	0.7	14.6	1.4	0.3	6.3			
55	Rozbórz	60	10.8	10.4		4.1				0.2	3.2	0.5	2.8	5.1	0	1.4	0.5	1			
56	Rozbórz	51.6	19	12.6	0.1	4.7					2.6	1	0	1.6	0	3.1	0.8	2.9			
57	Rozbórz	62.4	6.3	1.7		0.8					0.8		0	0.4	14.2	0.4		13			
58	Rozbórz	56	14.5	11		8	0.1			0.1	2.1		0.9	0.7		5.1	0.1	1.4			
59	Rozbórz	54.1	7.6	3.9		1.5					0.6		0.9	10.3	12.7	4.5		3.9			
60	Świerszczów	57.6	2.3	7.3		0.6									9.9	5.5	0	16.6			0.2
61	Świerszczów	56.4	6.2	5.7										3.5	9.5	11.7		7			
62	Świerszczów	41.6	22.7	17.2	0.1	3.4					0.3		1.5		5.8	4	0	1.8		0.1	1.5
63	Świerszczów	57.1	14.2	3.2		0.3							0.8	0.3	21.7	0.3	0.3	1.8			
64	Świerszczów	56.2	4	13		3.7								0.5	5.8	2.7	0	13.5		0.1	0.5
65	Świerszczów	55.3	10.1	8.8		0.5					0.3		1	0.5	15.5	1.8	1.3	4.8			0.1
66	Świerszczów	61.3	4.7	11		0.4								0.6	11.9	1.8	0.3	7.7			0.3
67	Świerszczów	42.5	18.9	11.3		1.8							0.9	0.6	12.8	0.9	1.2	8.5			0.6
68	Świerszczów	45.6	5.3	16.2		0.9							0.3	1.5	23.5	1.2	0	4.7			0.8
69	Świerszczów	50.5	5.3	9.6		0.9				0.7	0.2		0.5	0.7	14.2	4.8		12.5			0.1
70	Isaiia, jud.Iaşi	45	16.8	13.4	0.5	1.4			0.8	0.8	3.4	0.3	0	1.1	0	0.6	0.8	5.9	8.9		0.3
71	Isaiia, jud.Iaşi	61	23.1	3.8		1					2	0.5	0.5			1.4		3.8	2.4		0.5
72	Isaiia, jud.Iaşi	52.8	9.9	14.1		1.5		1			2.2	0.6			1.6	0.6	1.9	9.9	3.5		0.4
73	Isaiia, jud.Iaşi	60.3	12.2	5.4		1.5					1.8		0.3	2.7		1.2	4.2	9.2	0.9		0.3
74	Isaiia, jud.Iaşi	66.7	10.6	5		3.1					1.4		1.4	1			2		8.6		0.2
75	Olteni, jud. Covasna	46.5	7.9	4.2		2.5	0.3	2.3			1.1		2.3	3.1	0	15.5	4.5	9.6		0.2	
76	Olteni, jud. Covasna	55.7	14	9.7		1.7	0.3		2.3		0.6	0.3	0.3	0.6	0	0.9	4.3	7.7		0.9	0.7
77	Olteni, jud. Covasna	54.7	20	3.3		1.8			1.4		6.9	2.9	0.4	1.8		4.7	0	1.4			0.7
78	Olteni, jud. Covasna	57.6	11.8	8.6		5		0.3			6.5	0.5	1	5.8		1.2	0	1.5			0.2
79	Mihoveni, jud. Suceava	68.7	10.3	12.8		3.5					0.6		1.3	0.3		2.2		0.3			
80	Mihoveni, jud. Suceava	53.7	16.3	9		2.9				0.3	3.4		0.6	0.6		0.6	4.6	8			
81	Preuteşti-Ciritei, jud. Suceava	70.5	2.3	13.3		4.9		0.6				0.3	1	3.9		0.6	0	2.3			0.3
82	Preuteşti-Ciritei, jud. Suceava	50.4	8	24.5		7.2		0.5		1.8	2.1		2.1	0.3		0.3	0	2.8			
83	Traian-Dealul Fântânilor, jud. Neamţ	52	7	7		3					2.5		0.6		12.6	8.2	1	4.6	0.2		1.3

84	Traian-Dealul Fântânilor, jud. Neamţ	81.1	6.5	3		1.2					2.4	0.3		2.7		0.3		0.6	1.5		0.4
85	Traian-Dealul Fântânilor, jud. Neamţ	58.2	16.1	6.9		4		1.2		0.3	3.5		0.6	2.9		1.4	1.7	2.9			0.3
86	Traian-Dealul Fântânilor, jud. Neamţ	52.6	10.5	13.2		9					0.9	0.6	1.5	0.3		0.6	1.8	8.4			0.6
87	Traian-Dealul Fântânilor, jud. Neamţ	59.9	20	7.1	0.3		3.8				3.2		1.3	1.9		1.3		0.3			0.9
88	Târpeşti, jud. Neamţ	55.3	14	13.5		4.3			0.3	0.6	1.2		1.2	0.9			3.5	2.6			2.6
89	Târpeşti, jud. Neamţ	39.2	19.1	13.6	0.3	3.7				0.3	1.9	1.1	0.8	1.3		1.6		1.3	14.4		1.4
90	Târpeşti, jud. Neamţ	60.7	14.3	7.5		2.2					1.6			1.2		3.1		1.9	6.5		1
91	Târpeşti, jud. Neamţ	79.4	8.7	2.8		1.4					0.9		0.9	1.8		2.3	0.9	0.9			
92	Târpeşti, jud. Neamţ	60.4	20.2	3.8		2.2					1.6		0.6	2.2			1	1.6	5.8		0.6
93	Tăşnad-Sere	44.4	14.4	17.9		7.4					1.4		0.2	2.9	0	4.5	0.5	5		0.1	1.3
94	Tăşnad-Sere	54.7	14.2	11.7		3.7					0.6	0.3		0.3			3.1	7.7		0.6	3.1
95	Tăşnad-Sere	46.3	20.7	12.7	0.1	5.5			0.3	3.2	0.9		0.3	1.7		0.9	1.2	5.5		0.1	0.6
96	Tăşnad-Sere	39.9	17.5	20.6	0.3	4.2	0.8	0.3		1.1			0.8	2.1		2.6	0.8	7.7		0.5	0.8
97	Tăşnad-Sere	52.3	15.6	16.2		4.5					0.3	0.3		1.6		3.9	0	3.6		0.1	1.6
98	Călineşti-Oaş	56.5	11.9	6.6		2.2	0.3		5.5	0.1	0.8	0.3	0.3	2.8		4.7	2.8	4.2		0.3	0.7
99	Călineşti-Oaş	51	13.2	11.2		1.4			6.3		0.3			5.7		1.1	0.3	8.9			0.6
100	Călineşti-Oaş	38.6	12.6	7.2	0.3	2.6	0.5		29		0.3		0.8	1		2.3		3.9			0.9
101	Călineşti-Oaş	54	11.2	10.9		3.4			5.6		0.6		0.6	5.3		2.8	0.6	4.7			0.3
102	Călineşti-Oaş	50.6	19.4	9.4		2.8	0.3		2.8		0.8		0.6	5.8		1.7	0.8	3		0.3	1.7
104	Homorodul	47.5	9.5	19.4	0.1	6.2				2.1	0.5		0.2	3.1		4.3	2.6	3.8		0.1	0.6
105	Homorodul	49.2	8.6	19.4		6.7		0.2		0.7	0.5		0.2	1		0.5	3.4	7.2		0.5	1.9
106	Homorodul	39.2	19.7	12.9		4.4					3.8	1.1	0.3	3.3		1.6	2.7	8.2		1.4	1.4
107	Homorodul	58.7	7	12.5		3				3	0.3	0.3	5.2	1.6			1.4	6.3		0.3	0.4
108	Halmeu-Vamă	51.4	14.7	4.7		1.4	0.1				2.5		0.5	1.6	6.3	2.9	2.9	9.9	1.1		
109	Halmeu-Vamă	47.8	14	13.3		3.5					2.9	0.6	0.9	2.9		0.6	4.3	8.4		0.2	0.6
110	Halmeu-Vamă	53.4	16.1	9		2.4					4.2			1.2			10.7	2.7			0.3
112	Halmeu-Vamă	51.2	13	8.5		3.6					5.4	0.8	0.5	0.3			13.4	2.8			0.5
113	Halmeu-Vamă	46.5	25.6	10		3.2				0.1	5.7	0.2	0.2	1		3		4.2		0.1	0.2
114	Halmeu-Vamă	41.4	26.2	17.5		4				0.5	3.9	2.6		1				2.1			0.8
115	Halmeu-Vamă	58	14.4	6.5		0.8					0.8		0.4	0.8	12.5	2.3		2.7		0.8	
116	Halmeu-Vamă	53.6	19	4.7		3.1					1.7	0.3		1	3.7	1.7		11.2	0		
117	Halmeu-Vamă	48	18.1	8		1.8	0.1				2.2		0.3	1.5	9.2	3.4		7.1			0.3
119	Pişcolt-Lutărie	38	16.8	15.1		5					7	0.2	2.2	1.7			10.1	2.7			1.2
120	Pişcolt-Lutărie	55.9	7.8	5.2		2.6					2.6			0.7		0.7	14.6	9.3	0.3		0.3
121	Pişcolt-Lutărie	50	15.3	0.9		1.5					3.9	0.9	0.9	2.7			10.6	12.4		0.3	0.6
122	Pişcolt-Lutărie	46	24	6.1		0.9					5.5	0.3	0.9	2.8			6.7	6.1		0.1	0.6
123	Pişcolt-Lutărie	51.3	17	11.1	0.2	1.7		0.5			2	0.2		0.2	10.6		1	3.7			0.5
124	Pişcolt-Lutărie	56.6	6.9	8		5.2	0.3	0.8			1.1		0.6				9.9	5	5		0.6
125	Pişcolt-Lutărie	49.7	12	3.4		1					1	0.1				1.5	17.6	12	0.1	0.1	1.5
126	Pişcolt-Lutărie	47.7	18.4	11.3	0.3	1.3				0.3	0.5		0.3			0.5	9.7	8.7		0.1	0.9
127	Pişcolt-Lutărie	57.1	8.2	4.5		0.9			0.2		1.1		0.7	0.5		0.2	8.2	15.6	2.5	0.1	0.2
128	Pişcolt-Lutărie	45.3	8.2	7.2		1.6					1.3		0.6	0.6	28.2	1.6	2.2	2.5		0.1	0.6
129	Pişcolt-Lutărie	54.1	5.7	8.1	0.3	0.5					1.9		0.3	1.1			13.5	14.1		0.1	0.3
130	Pişcolt-Lutărie	61.2	8.5	5.5		1.5		1.5			1.8		0.3	0.6			9.4	9.4			0.3
131	Pişcolt-Lutărie	52.7	11.9	9.1		0.5					4.1	0.5	0.3	0.5		0.8	10.6	7.3	1.3		0.4
132	Pişcolt-Lutărie	63	3	7.6	0.1	0.9				0.3	0.9					2.1	11.8	10.3			
134	Pişcolt-Lutărie	47.2	12.7	10.7		0.6				0.1	3.1			0.6			16.3	7.9		0.1	0.7
135	Pişcolt-Lutărie	51.7	13.8	9.8	0.1	6.7					0.8		0.8	0.3			8.4	7.6			
136	Pişcolt-Lutărie	49	13	7.8		1.3					1.9					3.5	13.7	9.4		0.1	0.3
137	Pişcolt-Lutărie	58.5	9	8.5	0.3	2.8	0.1				0.8		0.6	0.8		0.3	14.7	3.4			0.2
138	Căpleni-Drumul	47	7.7	6.4		0.6					0.6			0.3	15.4	11.3	0.1	10.3	0.3		
139	Căpleni-Drumul	61.5	7.7	4.4		1.5					0.5		0.3	0.5	12.9	1.3	0.5	8.8		0.1	
140	Căpleni-Drumul	47.1	6.8	7		1.6					0.3			0.8	2.7	4.9	21	7.1		0.3	0.4
141	Căpleni-Drumul	67	7.1	7.7		0.3					0.3		1.3			7.1	5.7	3.4		0.1	
142	Căpleni-Drumul	65.3	0.7	2.4							0.3		0.3			5.9	16.4	8.7			
143	Chişcăreni XIV	61.6	10.8	5.6	0.3	0.9										1.5	1.5	7.7	10.1		
144	Chişcăreni XIV	60.7	10.7	12.3		2.1					3.8	0.8	0.5	0.3				0.5	7.2		1.1
145	Bumbăta	54.5	20.7	13.1		1.8	0.5			0.1	1.3	0.3	0.5	0.5		1	1.8	3.9			
146	Bumbăta	64.4	11.5	11.8		2.6					2.3		0.3	1.3			0.3	0.3	4.9		0.3
147	Găureni	68.7	8.5	9.5		1.7					0.7			1		1.4	2.4	4.4	1.7		
148	Găureni	65.9	5.2	3.7							1.2		0.9	0.3		19.1		2.5	0.9		0.3

Tab. 2. Mineral and petrographic composition of the samples. Value in percentage.

Granulometric analysis measuring the grain diameter of crystal grains and clay clasts (*Quinn 2013*) were made for microscopic images of the thin sections. The length of section grains (500–1000 grains) in the picture was calculated using script in the MATLAB R2007b software applied to automatic image analysis. The calculation was made within the following ranges: 0.002–0.02 mm, 0.02–0.05 mm, 0.05–0.1 mm, 0.1–0.2 mm, 0.2–0.5 mm, 0.5–1 mm, 1–2 mm and ∅ > 2 mm. The analysis was based on the classification proposed by the Polish Society of Soil Science (Polskie Towarzystwo Gleboznawcze 2009). The samples were grouped according to hierarchical cluster analysis with the MATLAB R2007b software (cf. also *Kozłowski et al. 2014*, 55–60). Factor analysis (with the STATISTICA software) was additionally used for the same purpose. The examination started with mineralogical-petrographic composition and the following components was chosen for cluster and factor analysis: content of grains of silty fraction, quartz grains (>0.02 mm), clay clasts, grog, mica group minerals and organic material, presence of rounded grains, presence of angular fragments of rocks.

The raw materials

The analysed areas (*fig. 1*) are dominated by loess, particularly in the uplands, often settled by Danubian communities in the Neolithic. The loess soil covers Miocene sediments in many places, which is typical not only of Małopolska (Little Poland). Miocene and silty clays have often been identified as the raw material used in the production of ceramic vessels. Miocene clays are easy to identify, while the reverse is true of alluvial deposits, more varied in composition, usually combining such sediments as the substratum of river valleys (Miocene clay in this case), sediments cut by river valleys (loess soil) or detritus material flowing along with rivers (Jurassic material in this case).The alluvial sediments are mostly dominated by silty fraction of quartz and particles of flint, chalcedony and micrite (lime mud; cf. *Kozłowski et al. 2014*, 52–53).

Miocene heavy marine clay, with characteristic relics of plankton, volcanic glass and glauconite, seems to have been commonly used in pottery production. Other kinds of raw material include Holocene alluvial clay, containing grains of crushed flint and fragments of Carpathian flysch rocks, and – in fine ceramics – loess-like sediment. Moreover, calcium carbonate and calcium phosphate rich sediments have been recorded in some cases, e.g. in LBK pottery deposited in caves (cf. *Czekaj-Zastawny et al. 2017*, fig. 5).

All those types of raw material were altered while being prepared for the production of ceramics. The original composition changed in the course of storing, mixing and kneading the clay, which may now complicate the identification of the raw material used in the production (cf. *Czekaj-Zastawny et al. 2017*).

In the northern part of the Great Hungarian Plain, two kinds of clay can be distinguished. The first one, characteristic of the Zemplín area, is very silty with fine material, a significant content of muscovite and grains of feldspars. The second kind, typical of the Šariš region, has a lower content of quartz and muscovite, and its grains are coarser in size (*Kozłowski et al. 2014*; *Czekaj-Zastawny et al. 2017*). This division corresponds with two types of ceramic paste.

The technological types of ceramics of the LBK, the MC and the L-VC in Małopolska

The analysis made previously has identified the basic technological and mineralogical types of the LBK ceramics in south-eastern Poland. The first and second technological type, recorded in fine ornamented ceramics, is characterized by well sorted and mixed clay, sometimes containing an organic admixture. The third and fourth types are characteristic of cooking and storage ceramics. Cooking ceramics, medium-walled, were made of silty or heavy clay with sand and an organic admixture, while storage ceramics were made of poorly mixed heterogeneous clay with an admixture of organic material, sometimes with grog (cf. *Rauba-Bukowska et al. 2007*).

The MC ceramics from Rozbórz 42 in eastern Małopolska are usually made of well prepared homogenous mass with no mineral intentional admixture. Makers of coarse pottery tended to use ceramic paste with grog temper (*Kadrow – Rauba-Bukowska 2016*).

The MC ceramics from Targowisko 10–11 in western Małopolska are made of various raw materials, usually of clay with grains of sedimentary rock from Carpathian flysch (*Rauba-Bukowska 2014b*; *Kadrow – Rauba-Bukowska 2016*).

There are slight differences between the MC ceramics recovered from those two sites. At Targowisko 10–11, the way of clay preparing based on ceramic mass with grog and sand temper predominates. At Rozbórz 42, well-sorted clay is frequent, though grog temper was used in the production of coarse pottery. There is no intentional mineral admixture (*Kadrow – Rauba-Bukowska 2016*, fig. 4).

Two types of ceramic fabric used in the production of the L-VC ceramics have been identified at Świerszczów 3 in eastern Małopolska (*fig. 1: 7*). The first, more common, type is characterized by the use of heavy clay (very small content of silty fraction) in which numerous rounded quartz and feldspars grains are visible; the mass also contains grog fragments and intraclasts of unmixed clay. That type of mass has many planar voids and cracks, probably because the vessels were shaped out of too wet heavy clay. The second type of the ceramic paste in the L-VC pottery is silty clay with grog temper.

Similar results have been obtained in the technological analysis of ceramics from Modlnica 5 in western Małopolska, dated to the same period (*fig. 1: 1*; cf. *Rauba-Bukowska 2011*, 568–573, pl. XXIII–XXXI).

The petrographic groups of ceramics in the northern part of the Great Hungarian Plain

The ceramics produced in the late phase of the Stračevo-Criş culture can be divided into coarse and fine varieties. The coarse vessels (e.g. sample no 104, cf. *tab. 2*) are made of clay with an admixture of sandy fraction, while the fine items (e.g. samples no 102; cf. *tab. 2*) are shaped out of fine-grained clay, sometimes with an admixture of bigger grains of volcanic rock. The analysis has shown that the raw material was prepared in the same way. The paste consisted of fine-grained clay with numerous coarser grains of minerals, mostly quartz and feldspars, sometimes flint, and fragments of volcanic or metamorphic rock, with

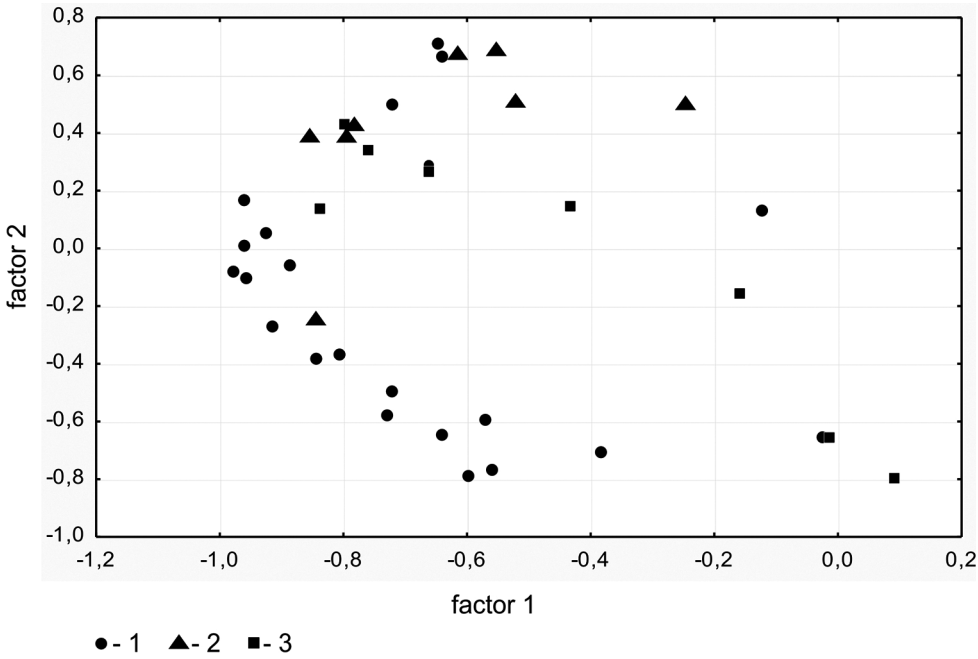

Fig. 3. Factor analysis of LBK pottery features from Kraków – Nowa Huta – Mogiła 62; 1 – pre-music note phase (I); 2 – music note phase (II), 3 – Želiezovce phase (III).

an organic admixture and with no grog temper. The samples differ slightly in their content of specific minerals and rocks.

The ceramics from Tăşnad (*fig. 1: 14*) are made of fine-grained silty clay with a significant amount of coarse clastic material. The analysed samples contain quartz, feldspars (c. 0.5 mm) and fragments of metamorphic rock (c. 0.1–0.2 mm).

The mass of clay in the ceramics from Călineşti (*fig. 1: 17*) is fine-grained, too, though it has a lower content of coarse clastic material. The analysis of the samples has also identified quite numerous fragments of volcanic rock, quartz and feldspars.

The ceramics from Homorodul (*fig. 1: 15*) are made of fine-grained clay with a significant amount of non-plastic inclusions. The analysis has recorded angular grains of feldspars, quartz, polycrystalline quartz, flint, fragments of metamorphic rock, fine grains of amphiboles and sometimes rutile (c. 0.1 mm).

The pottery produced by the Tiszadob-Kapušany group of the middle ALPC is characterized by fine-grained ceramic paste with a small organic admixture. Its mineralogical composition includes fragments of metamorphic rock – micaschists (*Rauba-Bukowska 2014a*).

The ceramic mass used by the Bükk culture, an element of the younger ALPC, is distinctly fine-grained, pure and very dense. Characteristic elements are difficult to find in that silty type of clay, but the fine-grained mass contains small grains of feldspars, mica flakes and heavy minerals (*Rauba-Bukowska 2014a*).

The content of clay minerals in the material used in the production of ceramics by the Tiszadob-Kapušany and the Bükk cultures ranges between 35 % and 72 %; that of quartz –

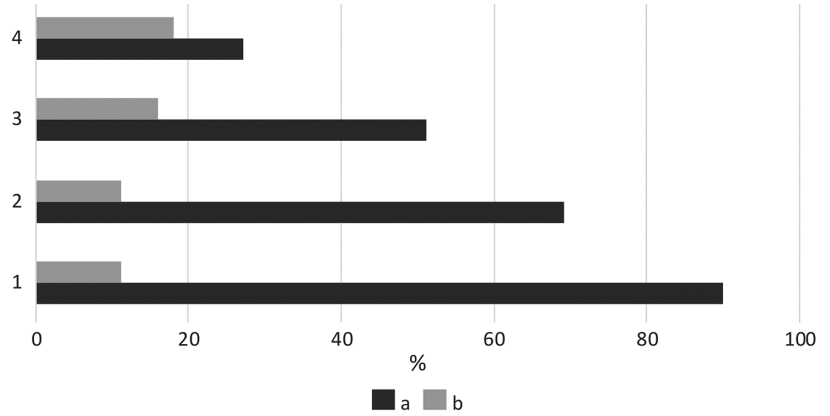

Fig. 4. Frequency plot of grog (chamotte) and organic admixture in LBK and ALPC pottery; a – organic admixture, b – grog (chamotte) admixture; 1 – LBK, phase I; 2 – LBK, phase II; 3 – LBK, phase III; 4 – ALPC.

between 18 % and 48 %. The entire ceramics are made of fine-grained and well sorted mass of clay with no admixture of coarser non-plastic inclusions; organic material is very rare. A number of the vessels are made of silty clay with a small content of feldspars; some are enriched with muscovite (*Czekaj-Zastawny – Rauba-Bukowska 2014*; *Czekaj-Zastawny et al. 2017*).

The Pişcolt group of the ALPC (*fig. 1: 12, 13, 16*) used two types of ceramic fabric, with the first type additionally divided into two subtypes. The mass in subtype 1a is fine-grained, with a small amount of quartz pellet and with numerous particles of an organic admixture. The mass in subtype 1b has a considerable amount of quartz pellet with a large organic admixture. The second type of the mass contains grog temper and usually no organic fragments.

The ceramics produced by the post-ALPC Iclod group are made of homogeneous fine-grained silty clay with grog temper. The mass contains no organic fragments, which makes the Iclod ceramics different from the previously described vessels produced by the Pişcolt group.

Concluding remarks

Through the conducted research we managed to achieve several goals assumed in the introduction of this article. The reconstruction of the rules governing the selection of ceramic raw material and considering certain technological aspects of the production of ceramic vessels in LBK and younger Danubian cultures allowed us to formulate some conclusion about the development of Neolithic communities in the south-eastern part of Poland and east of Carpathians.

a) The evolution of the LBK ceramics

The unpublished petrographic analysis of pottery from Site 62 in Nowa Huta-Mogiła, which has been dated to every phase of the LBK (*figs. 1* and *2*), identified the basic trends in the evolution in clay preparation (*figs. 3* and *4*).

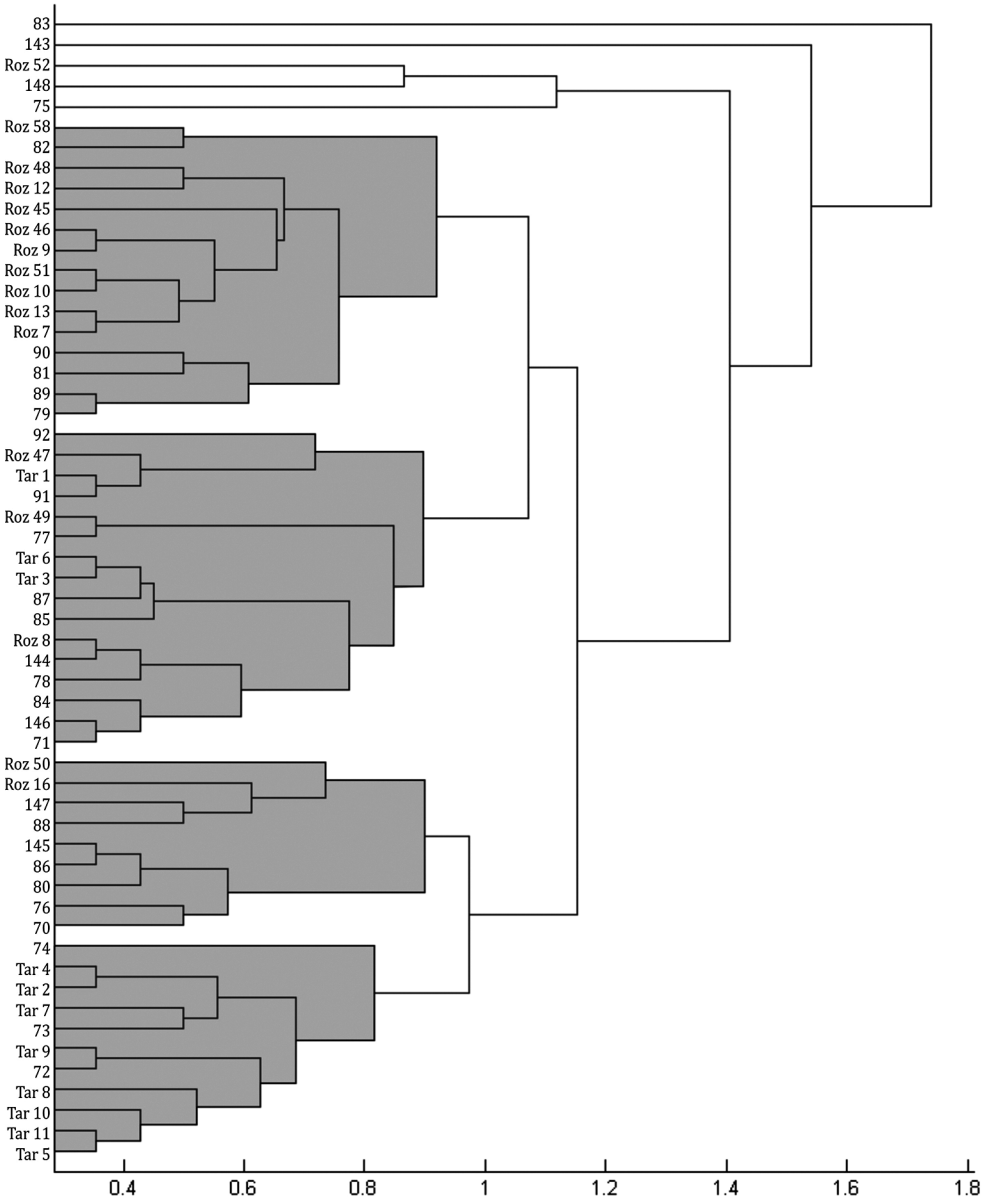

Fig. 5. Cluster hierarchical analysis of LBK pottery samples from Targowisko 10–11, Rozbórz 42 and from sites in Moldova (Romania and Republic of Moldova) in the form of dendrograms.

The content of organic material in the ceramic fabric used by the LBK changed with time and depended on the type of pottery. It has been recorded in 90 % of the analysed ceramic fragments dating from phase I (e.g. at Site 2 in Zagórze; *fig. 1: 3*); in 53 % of fine pottery and 97 % of coarse pottery in the classic phase (II); in 37 % of fine pottery and 75 %

of coarse pottery in the late phase (III). In the younger (III) phase of the LBK, the content of silty raw material increased in comparison to phases I and II. Statistically, the ceramics from the younger (III) phase of the LBK became similar to the ALPC ceramics (*fig. 4*; cf. *Czekaj-Zastawny et al. 2017*).

The ceramic material from other multi-stage sites in Małopolska (*fig. 1: 2–6*), as well as from eastern Romania (*fig. 1: 18–20, 24–26*) and from Moldova (*fig. 1: 21–23*) confirms the developmental trend in the clay preparation of the LBK ceramics reconstructed in the analysis of the material from Nowa Huta-Mogiła 62 (*fig. 1: 2*).

b) The influence of the ALPC on the evolution of the LBK pottery in Małopolska

One determinant of the technological changes in the LBK ceramics in Małopolska, especially in its late phase, was the adaptation of Transcarpathian influences of the ALPC in the LBK environment in Małopolska (cf. *Kaczanowska – Godłowska 2009*; *Kozłowski et al. 2014*; *Czekaj-Zastawny et al. 2017*).

The analysis of the ceramics from Site 17 in Brzezie has helped to distinguish imported vessels from the ALPC area from vessels which were produced locally, but which imitated the southern patterns (*Rauba-Bukowska 2014a*; *Czekaj-Zastawny – Rauba-Bukowska 2014*).

Those two kinds of ceramics differ primarily in the type of raw material used in their production, although both groups are made of silty clay. In the imported pottery, the average content of quartz amounts to 33 %, while the content of clay minerals is 51 %. Similarly, the pottery recovered from Brzezie 17 has the average content of quartz equalling 26 % and the average content of clay minerals equalling 67 %. The most striking difference, however, consists in the content of muscovite and feldspars. In the imported ceramics, the content of muscovite is 3.8 %, and that of feldspars is 4 %, while the imitations and the locally produced pottery have the contents amounting to 0.8 % and 0.4 %, respectively. The quantity of organic material in both kinds of ceramics is similarly very low. However, the locally produced pottery more often includes organic temper, destroyed to a greater or lesser extent (*Czekaj-Zastawny – Rauba-Bukowska 2014*; *Czekaj-Zastawny et al. 2017*).

The development of the LBK, phases I to III, was marked by the following trends: (1) the increasing use of silty clay; (2) the decreasing use of organic material as an admixture; (3) the use of grog in the mass of clay toward the end of the LBK evolution. The evolutionary changes in the LBK ceramics resulted mostly from intensifying contacts with the ALPC.

c) The technology of the LBK ceramics east of the Carpathians

The LBK ceramics from eastern Romania and Moldova differ considerably from the ceramics of the late Starčevo-Criş culture, of the Pişcolt group within the ALPC and of the post-Linear Iclod group in north-western Romania. Moreover, the vessels show no clear relationships with the post-Linear cultural units in Małopolska (the MC and the L-VC). However, the technology of the pottery is reminiscent of the LBK ceramic assemblages from Targowisko 10–11 (phases I and II; cf. *Rauba-Bukowska 2014b*) and Rozbórz 42 (phase III).

The LBK ceramic assemblages from Małopolska (*fig. 1: 5, 6*), eastern Romania and Moldavia (*fig. 1: 18–26*) have been subjected to hierarchical cluster analysis (*fig.* 5) with the MatLab programme. Eight traits have been examined: the content of silty fraction, coarser clastic material, clay clasts and micaceous minerals (muscovite, biotite) and also – as intentional admixture, presence of rounded grains, presence of larger angular fragments

of rocks and presence of grog. This qualities describe both: the choice of appropriate raw material and admixture which has been used to the clay. The quantities of the minerals have been ascribed to four categories: 1) absence; 2) small amount; 3) average amount; 4) large amount. The resulting dendrogram (*fig. 5*) illustrates close affinity of the discussed ceramic assemblages.

The dendrogram corroborates the widely accepted thesis that eastern Romania, Moldova and the adjacent parts of Ukraine (the Dniester basin) were settled by the LBK population from Małopolska at the beginning of phase II (cf. *Kozłowski 1985*; *Larina 1999*; *Dębiec 2012*, etc.). The ceramics from the eastern areas show no stylistic features of the Želiezovce phase (III). Consequently, some researchers (e.g. *Larina 1999*) conclude that LBK settlement in the Seret, the Prut and the Dniester basins was limited to phase II of the LBK. Since those areas have provided no ceramics whose technology would be related closely to phase II of the Małopolska LBK, the culture seems to have lasted much longer, even though no traces of the Želiezovce style have been recorded (*Kozłowski 1985*; *Dębiec 2012*).

d) The culture change at the turn of the LBK and the MC in Małopolska

The cultural change at the turn of the LBK and the MC has already been discussed elsewhere in the context of the developmental trends traced in the technology of ceramics (*Kadrow – Rauba-Bukowska 2016*). Two sites, Targowisko 10–11 in western Małopolska (*fig. 1: 5*) and Rozbórz 42 in eastern Małopolska (*fig. 1: 6*), have provided series of samples for comparison, with classic MC pottery recorded at both locations. Targowisko 10–11 was dominated by ceramics dated to the music-note phase (II) (cf. *Rauba-Bukowska 2014b*), while Rozbórz 42 mostly contained items from the Želiezovce phase (III) of the LBK.

The LBK ceramics from Rozbórz nad Targowisko differ considerably, which is due in part to their originating in various phases of the LBK evolution. The material from Targowisko 10–11 continues the older LBK traditions, as shown by the raw material used and the method of preparing the mass of clay. Potters at Targowisko 10–11 added an organic admixture to the mass and used unsorted clay with natural grains of various size. In Rozbórz 42, a well sorted mass was mostly used without an organic admixture, in the same way as in some ALPC traditions. Additionally, the ceramic mass of the LBK coarse pottery in Rozbórz 42 contained lumps of dry clay (*Kadrow – Rauba-Bukowska 2016*).

The LBK and MC ceramics from Rozbórz show essential similarities, especially as regards the raw material. Local potters mostly used well prepared homogenous mass of clay with no admixture. Certain differences can be observed in the coarse pottery. The mass of clay in the LBK items has no organic admixture, while the MC vessels are made of ceramic mass with grog temper.

The results of the technological analysis mentioned above confirm the hypothesis (based on other grounds; cf. *Kadrow 1990b*, 59–63; *Kadrow – Zakościelna 2000*, 241–244; *Kadrow 2006*) that the MC originated in eastern Małopolska, as proven by the technological similarity of the LBK and MC ceramics in Rozbórz 42. The new archaeological culture spread subsequently to the other areas of Małopolska from the eastern part of the region (*Kadrow – Rauba-Bukowska 2016*). Moreover, the similarity between the ceramics produced by the MC and by the late LBK is greater than the similarity between the products of the MC and those of the Iclod group, a post-ALPC cultural unit from the north-eastern Carpathian Basin.

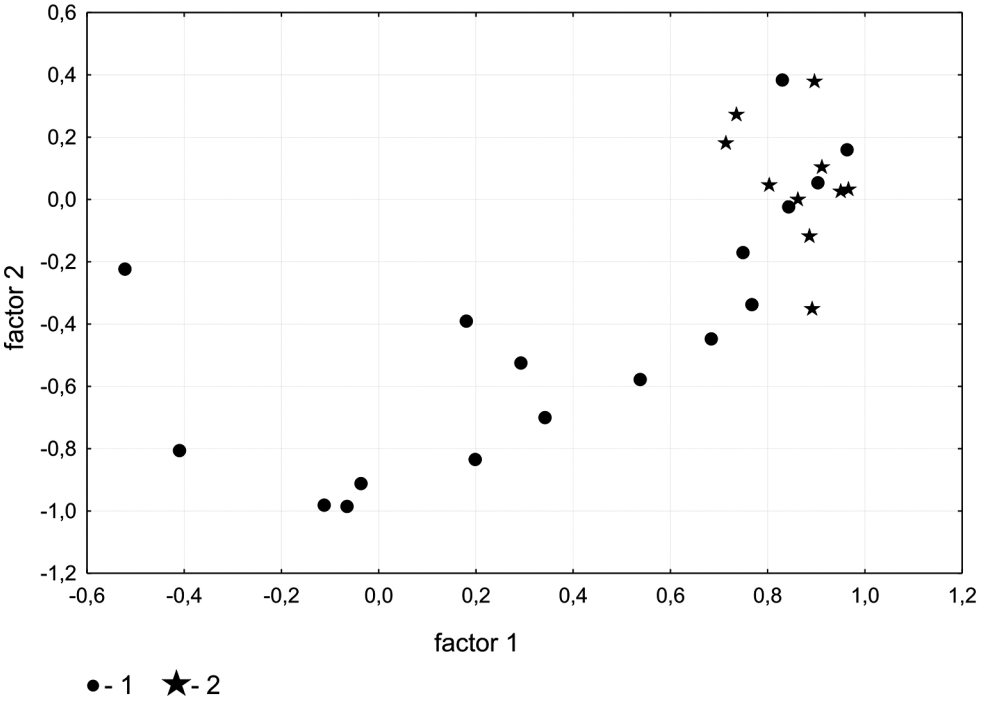

Fig. 6. Factor analysis of MC (Rozbórz 42) and L-VC (Świerszczów 3) pottery samples.

e) The culture change at the turn of the MC and the L-VC

Comparison of the MC ceramics with the L-VC ceramics (*fig. 6*) shows that the tendencies present already in the MC were continued and developed in the selection of the raw material and in the preparation of the mass of clay in the latter cultural unit. Changes in various elements of material culture, such as metallurgy, flint working or funeral rites, indicate that the population succumbed gradually to external influences. The influences, however, were mainly noticeable in the classic phase and they reached their highest point in the late phase of the L-VC. The early phase was dominated by local elements that continued the local MC traits, which points to the indigenous origin of the L-VC (*Kadrow 2016*, 30–33).

As it has been argued in the preceding sections of this paper, the tendency discernible at the turn of the MC and the L-VC may be considered as the culmination of a long process of change in the technology of ceramics in Małopolska from the early Neolithic to the early Eneolithic periods. The process was local in character, though it was also shaped by external factors, especially by the ALPC affecting the production of ceramics in the late phase (III) of the LBK in south-eastern Poland.

The change consisted in the gradually decreasing content of organic admixture, still discernible in some of the MC ceramics, and in the increasing content of grog (*fig. 7*), which was used sporadically in the late LBK and became the dominant temper in the L-VC. The technology of production was less and less frequently adjusted to particular categories of

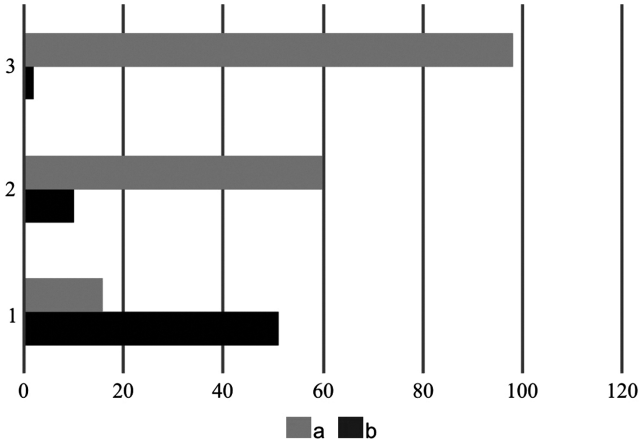

Fig. 7. Frequency plot of grog (chamotte) and organic admixture in LBK, MC and L-VC pottery in Małopolska; a – organic admixture, b – grog (chamotte) admixture; 1 – LBK, phase III; 2 – MC; 3 – L-VC.

vessels. The LBK still distinguished clearly the technological categories of serving vessels, cooking vessels and storage vessels, while in the MC, fine ceramics were technologically different from coarse ceramics. The L-VC, however, made no technological distinctions between the types of pottery which served different purposes.

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