A C T A   A R C H A E O L O G I C A   C A R P A T H I C A
VOL. LIII (2018): 97–128   PL ISSN 0001-5229

Magdalena Okońska, Małgorzata Daszkiewicz, Ewa Bobryk

Ceramic technology used in the production of easily abradable pottery (Pakoszówka-Bessów type) from Bessów site 3 in the light of archaeometric analysis

Abstract: The term Pakoszówka-Bessów type pottery is used to describe a specific kind of wheel-made pottery with easily abradable surfaces mostly dated to the 3rd century AD. Site 3 in Bessów, Bochnia Commune, Lesser Poland, is located in the dense Przeworsk culture settlement micro-region occupying the right bank of the lower reaches of the Raba River. The most characteristic feature of locally produced artefacts from Bessów, and to a lesser extent from other sites in the region, is the presence of enormous amounts of this pottery. The aim of laboratory analyses carried out on Pakoszówka-Bessów type pottery from Bessów was to verify the hypothesis that abradability of sherd surfaces is attributable to the alteration effect.

Key words: archaeometric analysis, chemical analysis, MGR-analysis, Przeworsk culture, wheel-made pottery

I. INTRODUCTION

Site 3 in Bessów, Bochnia Commune, Małopolska Province lies within a settlement micro-region on the right bank of the lower reaches of the River Raba (Fig. 1). The results of excavations carried out at this site have been published over a number of years (Cetera, Okoński 1994; Okoński 1996; 1999-2000; Kordecki, Okoński 1999; Przychodni 1999-2000; Okoński *et al.* 2000). In addition to the remains of a pottery kiln, excavations at the Bessów settlement also encompassed a feature referred to as a 'potter's depot', which is currently interpreted as a potter's workshop or part of one (Fig. 2; Okońska, 2018). A large assemblage of ceramics with smooth, readily abradable surfaces was recovered from the settlement. Comprehensive archaeometric analysis was carried out on sherds of this type from Bessów (see section III). Clay samples taken from the vicinity of the site were also analysed.

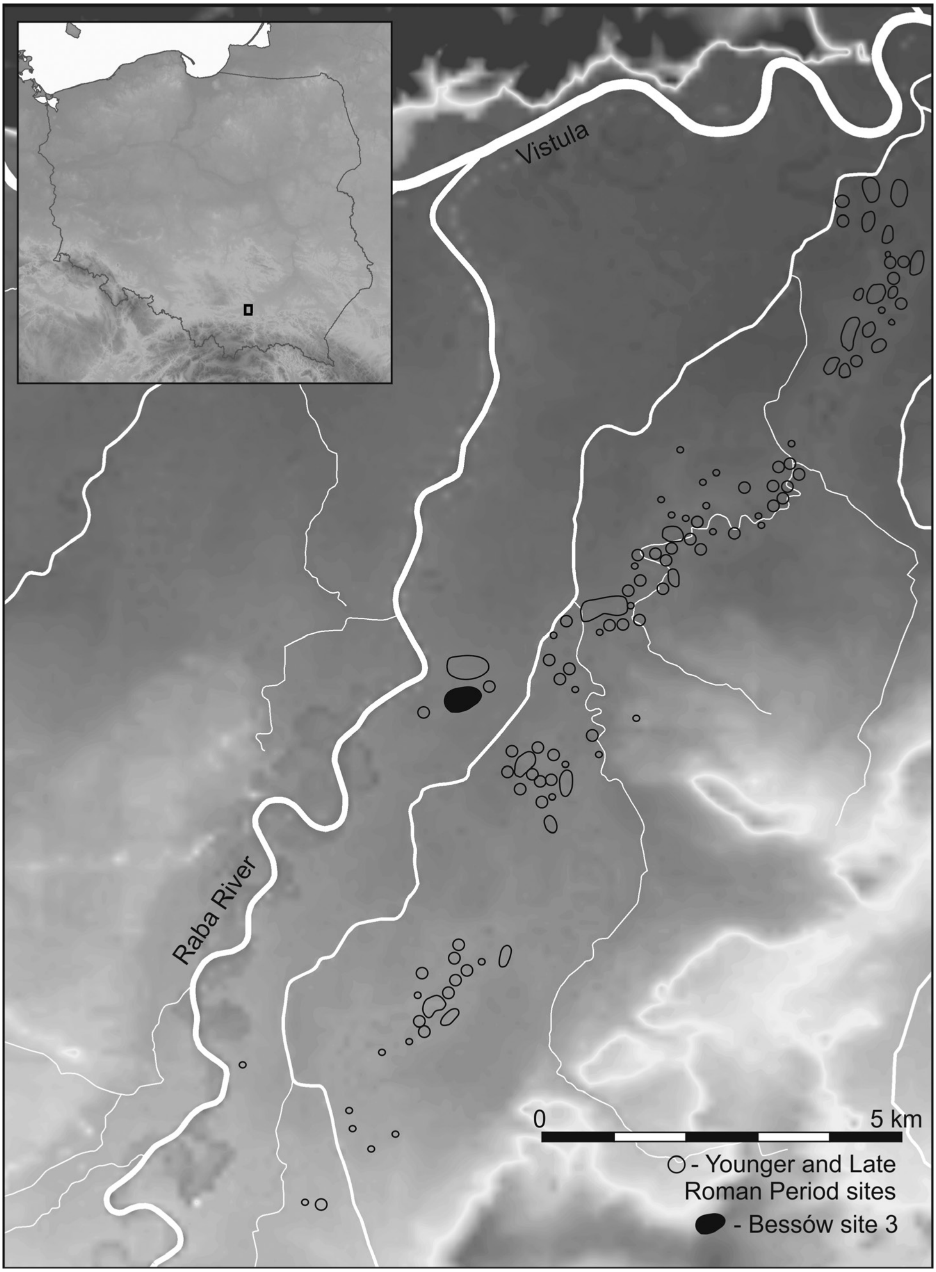


Fig. 1. The map of micro-region on the right bank of lower reaches of Raba River (after Okoński 1999-2000, Ryc. 2)

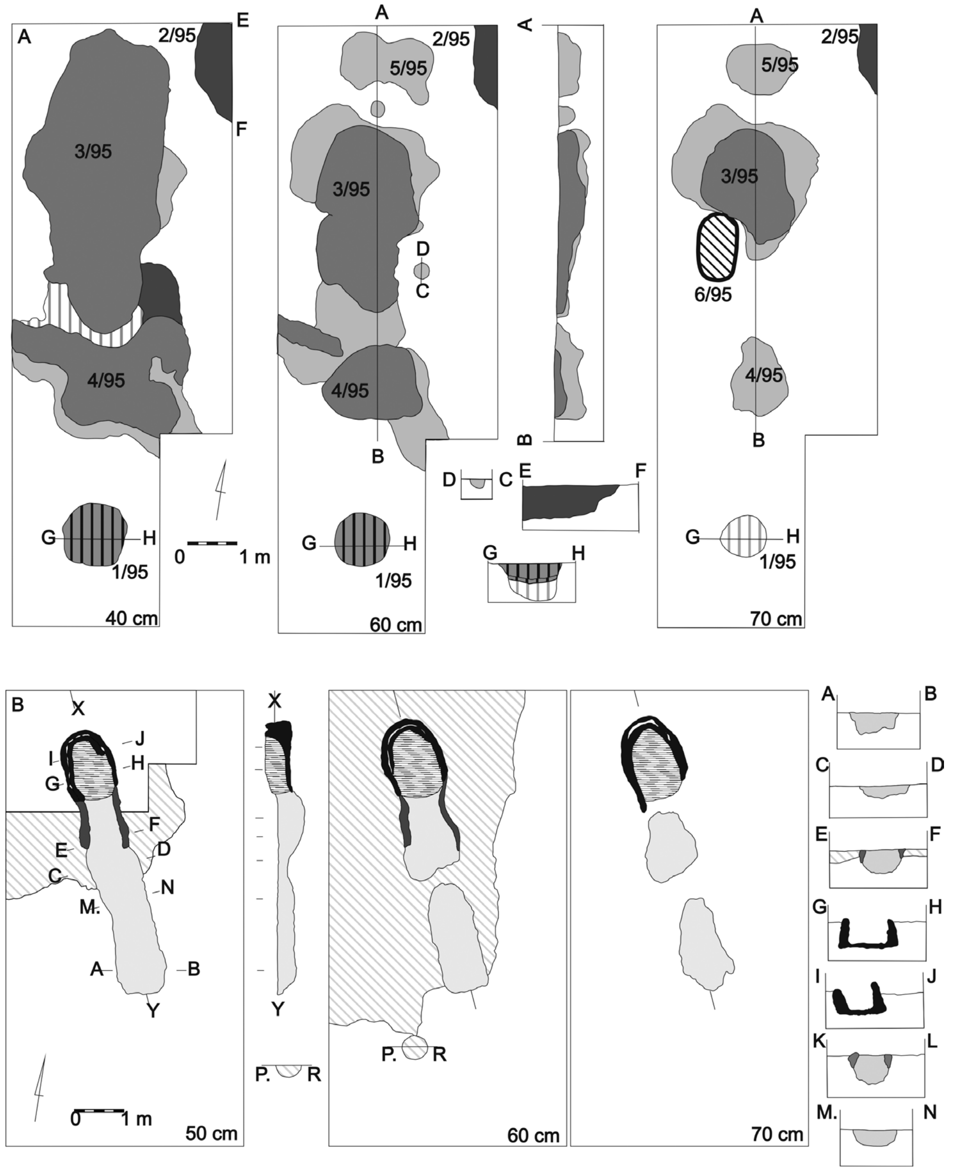


Fig. 2. Features excavated in Bessów, site 3. A – the "pottery depot", B – pottery kiln (after Okoński 1999-2000, Ryc. 4, 5A, 16, 17)

II. PAKOSZÓWKA-BESSÓW TYPE POTTERY

Around 22,000 ceramic sherds were recovered during the excavations at Bessów site 3. Of these, 8,576 were sherds of easily abradable pottery[1] (Fig. 3), leading to the definition of a ware known as Pakoszówka-Bessów type pottery. This term was introduced by Jerzy Okoński in reference to a characteristic group of wheel-made ceramics with easily abradable surfaces, which were linked to south-eastern cultural traditions associated with Dacian cultures (Okoński 1999-2000, 163-164). This type of pottery usually represents tablewares with smooth surfaces made of fabrics without any intentionally added mineral temper, or else tempered with small amounts of quartz sand, or occasionally with fragments of rock or grog. Small patches of variously coloured slip which prevented the surface from abrading survive on some of the sherds (Fig. 4: 1-9, 8:BES25-27, 29, 37/38, 41). A range of coatings was noted on only 441 of the 8,576 sherds of this type from Bessów

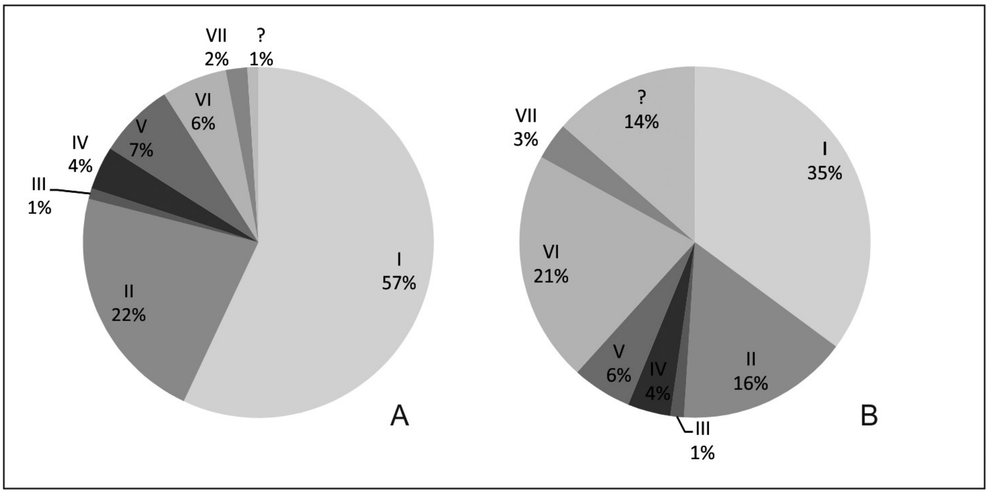


Fig. 3. Bessów, site 3. Percentage presence of technological groups distinguished for pottery material. I – wheel-made, abradable Pakoszówka-Bessów pottery type, 2 – wheel-made, non-abradable pottery, 3 – wheel-made, hard, fine grey pottery, IV – wheel-made, coarse pottery (tempered with sand), V – wheel-made, coarse pottery (tempered with rock and gravel), VI – sherds of storage vessels, VI – hand-made, coarse pottery (A – excavation season 1995; B – excavation season 1998)

[1] The Bessów pottery has been reanalysed in recent years (Okońska, 2018), and thus certain statistics cited herein differ from those in the earlier literature (Okoński 1999-2000).

site 3, amounting to 5.1% of the entire assemblage (Daszkiewicz *et al.* 2018, 50; Okońska, 2018). These were mainly very thin layers of a smooth coating which was usually the same colour as the pottery surface, though a slightly darker shade. In most cases these coatings survived on outer surfaces (Fig. 4: 1-9; 8: BES25), often in the recesses of decorative motifs (Fig. 4: 1, 2, 4, 9; 8: BES29), though some examples were also noted on inner surfaces (Fig. 4: 2, 3). In two instances the layers were somewhat thicker, both of them with matt black surfaces (Fig. 8: BES37/38, BES41).

Sites where Pakoszówka-Bessów type pottery has been found have also occasionally yielded sherds of pottery with rough, easily abradable surfaces[2]. At the same time, pottery with non-abradable surfaces is always noted at sites where pottery with abradable surfaces occurs.

In present-day Poland these types of sherds are found almost exclusively at sites dated to the Younger and Late Roman period. Their frequency at these sites ranges from single sherds and small ceramic series to large assemblages. They are found in greatest numbers at sites in the country's south-east. A distinct concentration of this type of pottery has been noted at sites of the Younger Roman period in the Beskidy region, among the foothills known as the Bukowskie Foothills and along the border with the neighbouring Dynów Foothills, where sherds of this type have been found at multiple settlement sites identified by fieldwalking survey, and where numerous assemblages have been recorded during excavations at site 26 in Pakoszówka, Sanok Commune, Podkarpackie Province, site 54 in Sanok, Sanok Commune, Podkarpackie Voivodeship, (Madyda-Legutko 1996, 73-76, list IV.1, map; Madyda-Legutko, Pohorska-Kleja 2004; Madyda-Legutko *et al.* 2004, 2008; Madyda-Legutko *et al.* 2006, 79), and at the recently excavated site 59-60 in Sanok. Smaller assemblages have been found at settlement sites excavated in the Nowy Sącz region, in the Jasło Foothills and on the outskirts of the Lower Beskids mountain range (Madyda-Legutko 1996, 74-76, list IV.1, map 5). Pottery with readily abradable surfaces has also been noted at a settlement site in Nienowice (site 17), Jarosław Commune, Podkarpackie Province, which lies much further north of the area under discussion (Bohr 2015, 198). Solitary sherds of this type of pottery have also come to light at a settlement dated to the end of phase B2 and phase B2/C1 in Tarnowiec, Tarnów Commune, Małopolska Province (Szpunar, Okoński 2004, 478 – 479, 484), and at site 5 in Koszyce Wielkie, Tarnów Commune, which is dated to the end of the Early Roman period and to the Younger and Late Roman period (Szpunar, Szpunar 2004).

Pakoszówka-Bessów type pottery is particularly abundant at Younger and Late Roman period sites of the settlement micro-region on the right bank of

[2] Pottery of this type was found, for example, at site 13 in Wrzępia, Szczurowa Commune, and site 2 in Bessów, Bochnia Commune, Małopolskie Voivodeship.

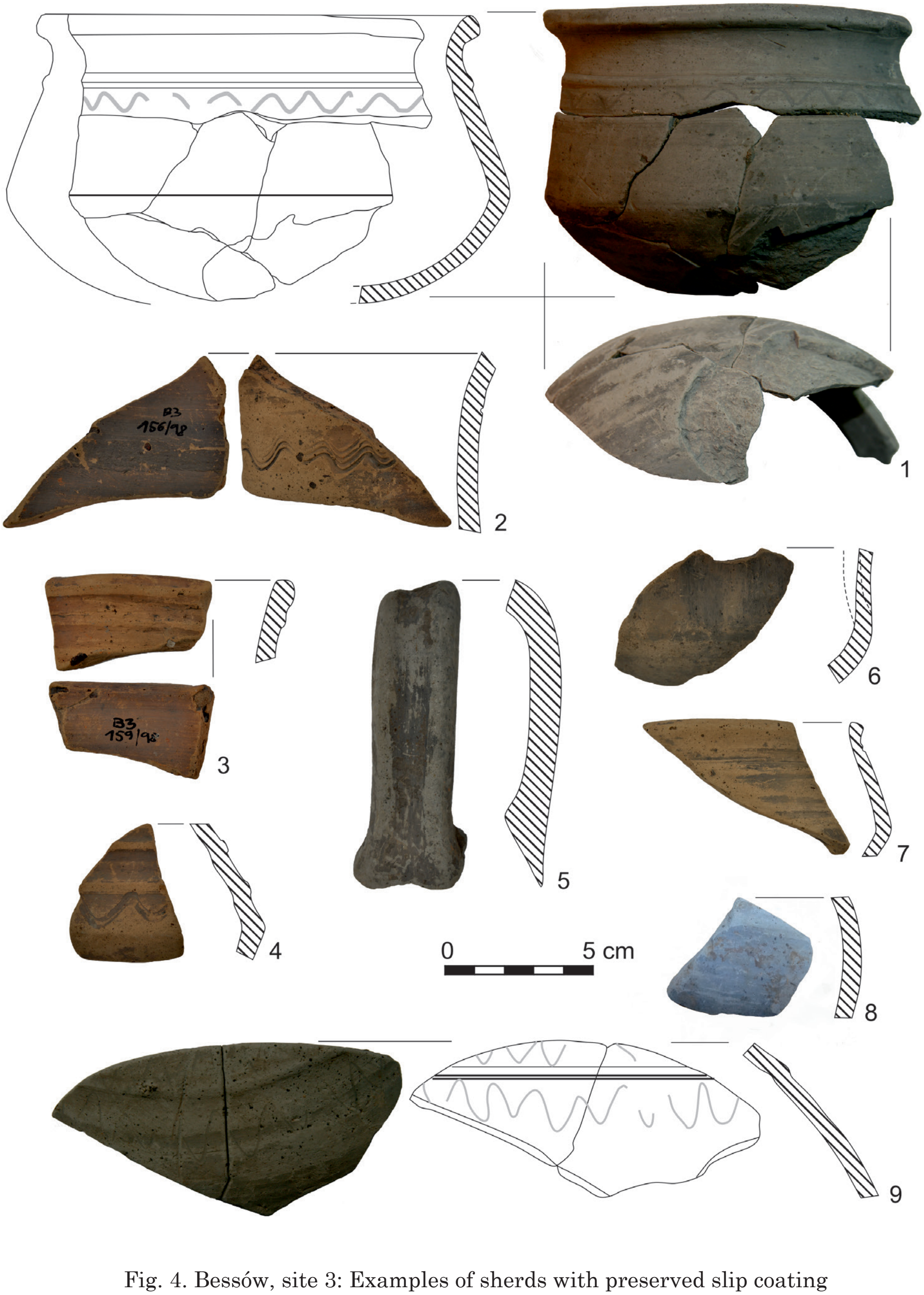


Fig. 4. Bessów, site 3: Examples of sherds with preserved slip coating

the lower Raba. This area has been investigated predominantly through fieldwalking surveys (Cetera, Okoński 1994). Trial trenching carried out in the area led to the discovery of sites featuring pottery kilns: Okulice site 18, Bessów site 3 and Strzelce Małe site 13 (Cetera, Okoński 1994; Okoński 1996; 1999-2000, 2001; Kordecki, Okoński 1999, 2001; Okoński *et al.* 2000). At Bessów site 3 pottery of this type was also recovered from features dated to the end of the Early Roman period and the transition between phases B2 and C1 (Okoński *et al.* 2000, 265, 266, 268).

Pottery with abradable surfaces has also been found at Przeworsk culture sites near Kraków: Kraków-Kurdwanów site 8, Kraków-Bieżanów site 15, and at Stanisławice site 15 (Dobrzańska *et al.* 2004, 680; Rodak 2010, 7), as well as at Kraków-Przywóz site 2 – a settlement where sherds of this type were found in the fill of a potter's kiln and elsewhere[3]. In addition to the areas already mentioned, pottery with abradable surfaces has also been found east of the Vistula, at a settlement site featuring pottery kilns in Tropiszów, and at site 12 in Chabielice, Łódź Province (Dobrzańska *et al.* 2004, 680).

Further afield of Przeworsk culture settlement, particularly large amounts of wheel-made pottery with readily abradable surfaces have been found at Carpic culture sites (Vîrtişcoiu-Poieneşti) in the river basin of the Prut and Siret, in the Geto-Dacian cultural orbit (Militari-Chilia), in eastern Slovakia, and also among the pottery wasters from kilns at the Beregsurány site in north-east Hungary (Dobrzańska *et al.* 2004, 679-680). Sherds of this type have also been recorded at the production site in Medieşu Aurit, north-west Romania[4], as well as in the Dniester basin, at the interface of the Lipitsa and the Przeworsk cultures (Madyda-Legutko 1996, 73-78; 2010, 29; 2011, 297-300; Kozak 1999).

Notably, larger assemblages of this variety of pottery are found at production sites with pottery kilns, usually in the fill of these kilns or in features associated with pottery production, such as the workshops at Bessów (Okoński 1999-2000, 120-135; Okońska, 2018) or Strzelce Małe site 13 (Okoński, 2001). This suggests that these sherds may represent wasters, although we cannot rule out that it is simply a reflection of excavation bias. It must be pointed out that sites along the lower reaches of the Raba were investigated through rescue excavations focusing on features (in particular pottery kilns) that were being destroyed by farming activities (Kordecki, Okoński, 1999, 184). At sites along the upper San, sherds of this type are most commonly found on settlement sites, usually in contexts not associated with pottery production.

---

[3] I am grateful for this information to Piotr Wawrzyniak and Mateusz Wawrzyniak of Poznań. This material was presented at the international conference *Pottery – the main source of knowledge for cultural change in the Central European Barbaricum*, held at the Faculty of Historical Studies, Adam Mickiewicz University, Poznań on 27-29 September 2017. The relevant paper will appear in the post-conference publication.

[4] I am grateful to Dr Robert Gindele of the Muzeul Județean Satu Mare (Satu Mare County Museum) for this information.

There is an ongoing debate in the literature about why it is that pottery with abradable surfaces occurs at Przeworsk culture sites. On the one hand it is argued that its presence represents a cultural phenomenon rooted in Dacian cultural traditions (Jamka 1939/1948, 206; Madyda-Legutko 1996, 77-78, 90-91, 107-108; 2004, 80; 2010, 28; 2011, 297-300; Madyda-Legutko, Pohorska-Kleja, 2004; Madyda-Legutko *et al.* 2004, 695; 2008, 11-12; Kordecki, Okoński 1999, 212-213; Okoński 1999-2000, 153, 163-164). To support this theory its proponents point to the fact that this type of pottery appeared at the same time as the potter's wheel was first used in Przeworsk culture ceramic production, which, according to current thinking, was supposed to have come about thanks to contacts with Dacian cultures, and to the fact that it is noted predominantly in the Younger Roman period (Godłowski 1977, 197-181; Dobrzańska 1980, 133-140; 1982, 90-92; 1990: 110-111; Rodzińska-Nowak 2006, 169-177; 2010, 2011; 2018). As mentioned earlier, Pakoszówka-Bessów type pottery is found only sporadically at sites dating from the end of the Early Roman period or its transition to the Younger Roman period. In addition, vessel forms from Pakoszówka (site 26), where a large assemblage of sherds with abradable surfaces was recovered from an excavated feature, and from other sites along the upper San, clearly reflect Dacian ceramic influences (Madyda-Legutko 1996, 73-78, 90-91, 107-108; 2004, 80; 2010, 28; 2011, 297-300; Madyda-Legutko, Pohorska-Kleja, 2004; Madyda-Legutko *et al.* 2004, 695; 2008, 11-12; Rodzińska-Nowak 2018, 315).

On the other hand, ceramic technology is also viewed as a potential explanation. It is suspected that the abradability of the pottery surfaces may be attributable to errors in the production process: a poor ceramic recipe, firing the pottery at temperatures inappropriate for the recipe, or a combination of these two factors (Dobrzańska *et al.* 2004; Dobrzańska 2015, 404-405). It is worth highlighting that researchers carrying out laboratory analysis put forward a working hypothesis linking abradability to the alteration effect (Dobrzańska *et al.* 2004, 686). However, this hypothesis has not been confirmed – analysis of the pottery found at Bessów site 3 also negates this theory (Daszkiewicz *et al.* 2018, 53).

We must, however, be mindful not to generalise the findings of earlier archaeometric analysis, above all because to date it has only been carried out on a small number of abradable sherds. Archaeometric analysis has encompassed two samples of pottery (abradable and non-abradable) discovered at Chabielice site 12 (Łódź Province), one sample of abradable pottery from site A in Moszczenica Wyżna near Nowy Sącz and – for comparison – a non-abradable sherd from Zofipole (Dobrzańska *et al.* 2004), as well as 6 samples (1 abradable and 5 non-abradable) from site 54 in Sanok and site 26 in Pakoszówka (Stobierska *et al.* 2008).

The only consistent finding of these analyses is that they have all disproved the hypothesis that surface abradability is attributable to the alteration effect. Abradability is dictated by one (or several) stages of the technological process.

Other results have been less unequivocal: for example, abradable ceramics from Chabielice and non-abradable ceramics from Zofipole have a similar specific surface area (defined using the BET method), whilst the specific surface area of an abradable sherd from Moszczenica is much greater, though comparable to that of a non-abradable sherd from Chabielice (Dobrzańska *et al.* 2004, tab. 1, p. 682). These results are fairly surprising, as one would expect to see a close correlation between specific surface area and surface abradability.

Nothing has been deduced about what factors are responsible for surface abradability, though conclusions have been drawn about ceramic recipes and original firing temperatures, and it has been suggested that vessel surfaces may have been coated with "a more fine-grained or more thoroughly levigated" than that of the sherd's core (Stobierska *et al.* 2008, 27).

III. LABORATORY ANALYSIS OF POTTERY FROM BESSÓW SITE 3

The aim of laboratory analysis carried out on Pakoszówka-Bessów type pottery from Bessów was to verify the hypothesis that abradability of sherd surfaces is attributable to the alteration effect[5]. The results of preliminary analysis have already been published (Daszkiewicz *et al*. 2018, 50-53). The results of all analyses carried out to date are presented herein. The terms abradable and non-abradable are used respectively in this text as shorthand references to pottery with easily abradable surfaces and pottery with non-abradable surfaces. It must be stressed that in this article the term 'abradable surface' refers to a subjective assessment of abradability; abradability was not defined for any of the samples using a normalised method[6]. The surface abradability of Pakoszówka-Bessów type pottery from Bessów is defined as follows: running a finger over the surface of this pottery, without applying firm pressure, results in the removal of a thin film from the ceramic surface which leaves a stain on the finger. All that needs to be done to identify the colour of the resultant mark left on the sherd is to rub the sherd on a piece of paper. It should be emphasized that the abradability of the surface of these ceramic sherds is not strictly speaking an effect which is restricted to the surface alone. There is no abradable layer of a specific thickness below which we find the non-abradable parts of the sherd; in other words, the sherd surface remains abradable regardless of how thick a layer is removed from the surface. Hence it is in fact the entire sherd which is abradable. Thus, if it was responsible

[5] On the subject of the alteration effect in archaeological pottery see, for example, Schneider 2017, 162-180.

[6] No tests were carried out to determine abrasion resistance.

for abradability the alteration effect would have to affect the entire thickness of the sherd and not just a thin surface layer.

The first stage of analysis involved taking measurements using a portable energy-dispersive X-ray fluorescence spectrometer (pXRF). These pXRF measurements were performed on 42 sherds: 34 of them came from the fill of a pottery kiln and its nearest vicinity, and 8 were from a workshop.

This procedure was conducted at the Free University Berlin Excellence Cluster 264 TOPOI as part of a series of test measurements designed to evaluate whether the pXRF technique can be a useful tool in the analysis of ancient pottery[7]. Readings were taken using a Niton XRF analyser (XL3t900S GOLDD RF-Analyser, 50 kV Ag anoda, MINING software) calibrated on twelve ceramic reference samples analysed by WD-XRF. These samples had been prepared in the form of round discs made from very fine clay fired at 900°C or from very fine ceramic sherds[8]. Measurements were performed without helium, in a sample chamber, with an 8-mm measuring spot and a measurement time of 120 seconds (30 seconds per filter). A measurement surface was prepared on each of the 40 pottery fragments by creating a fresh break using tungsten-carbide-tipped pliers. Three measurements were then taken at three different points on the prepared surface of each sample. Furthermore, in order to check the chemical composition of the abradable surfaces as well as the surfaces of black coatings and old breaks, a series of extra measurements was performed on some of the samples. The results of these measurements revealed relatively good sampling precision (average cv < 5%)[9] when determining levels of silicon (Si), titanium (Ti), aluminium (Al), iron (Fe), potassium (K), vanadium (V), zinc (Zn), rubidium (Rb), strontium (Sr), zirconium (Zr) and barium (Ba). However difference between min cv and max cv was <10% only when determining concentration of Ti (Fig. 5). Levels of all elements, exept manganese (Mn) and calcium (Ca), were determined with acceptable analysis precision (precision of average). Levels of Ti, Fe, K, Cr, Rb and Nb were determined with good analysis accuracy[10], while analysis accuracy for Y and Zr was satisfactory.

Figure 6 shows the results of measurements by pXRF (Fe, K, Cr, Rb, Nb and Zr versus Ti) performed on fresh fracture surfaces (black squares) and in the case of nine selected samples on outer surfaces (grey diamonds), inner surfaces (white diamonds) and on old breaks (black X-marks). In all but one case, measurements performed on the surface of fresh fractures are characterised by a lower titanium content (< 1 wt.% TiO_2) in relation to measurements performed on the sherd

[7] Daszkiewicz, Schneider 2018
[8] Reference samples prepared by G. Schneider and M. Daszkiewicz.
[9] cv = coefficient of variation
[10] Accuracy was determined by comparing the results of pXRF measurements (performed on fresh fracture surfaces) with the results of WD-XRF measurements performed on the same samples.

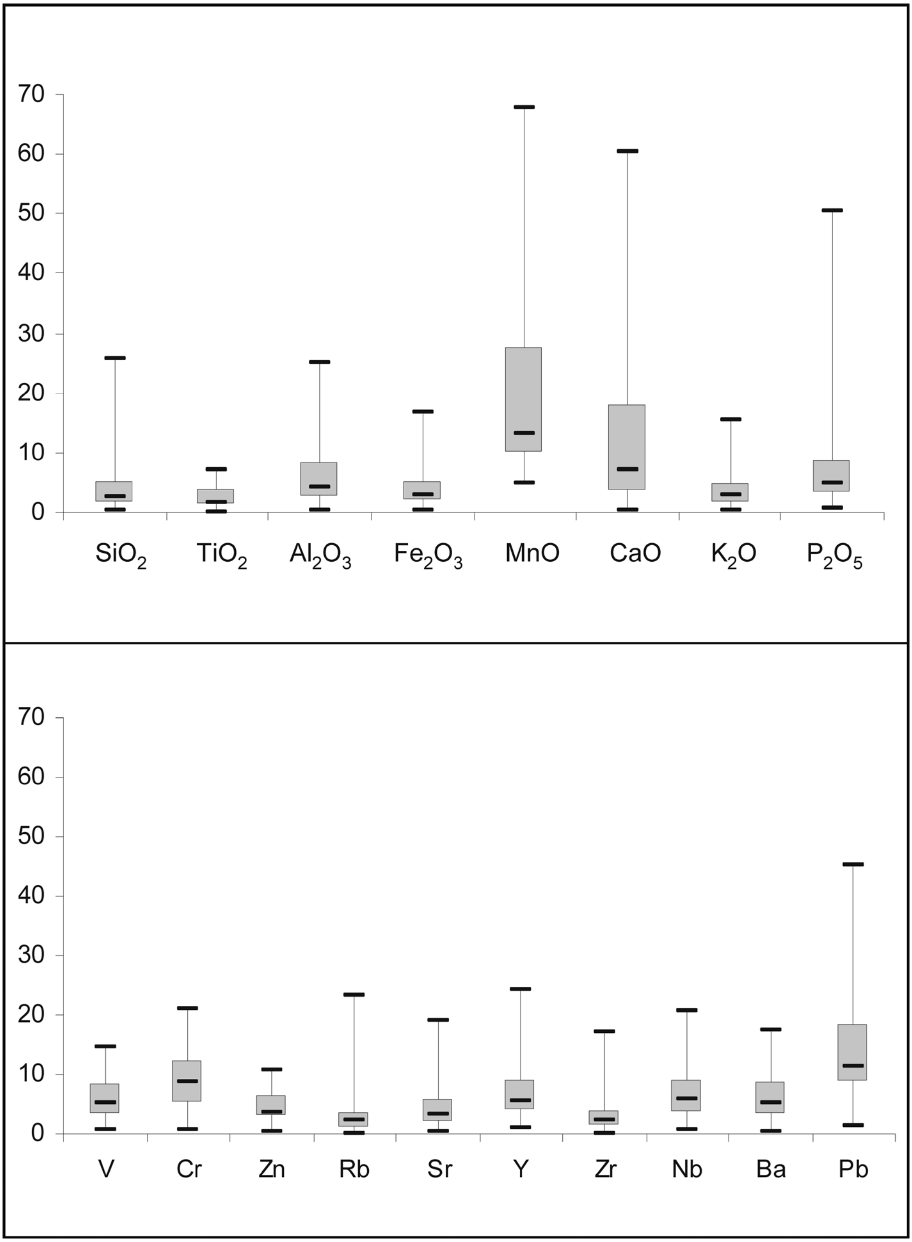


Fig. 5. Precision of sampling (cv%), measurement using pXRF
(measurements on fresh fracture surface).

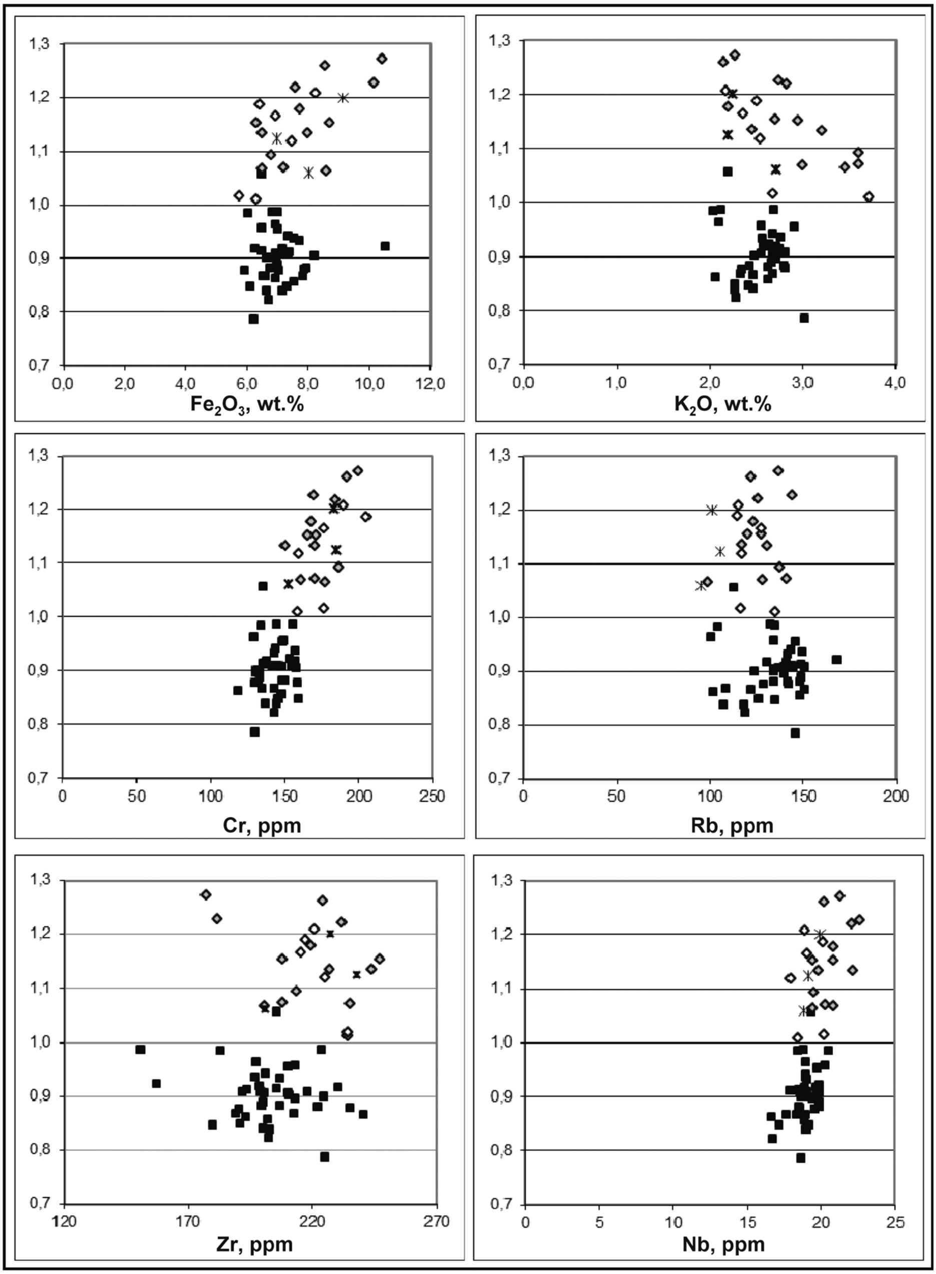


Fig. 6. Results of the measurements by pXRF, Y axis = in all diagrams, contents of Ti (as TiO_2 in wt.%); measurements on: fresh breaks (black squares); outer surfaces (grey diamonds); inner surfaces (white diamonds); old breaks (black X-marks)

surface and on old fractures (>1wt.% of TiO_2). At the same time concentrations of nearly all elements do not differ significantly, with the exception of Fe, K and Cr. The concentration of these elements is higher on outer surfaces of some samples. Phosphorous (P) levels (surprisingly, phosphorus content in samples from Bessów was determined with much better accuracy than was achieved for measurements taken on samples in other projects)[11] effect on the sherd surface and on fresh fractures are practically the same or if anything slightly higher when measured on a fresh fracture or on some of old breaks, though they are sufficiently low (average for measurements on fresh fractures – 0.5 wt.%, on outer surfaces and old breaks – 0.4 wt.%) to warrant speaking of the alteration (exept six samples with P contents > 0.8 wt. %). There were also no significant differences noted in levels of barium (Ba), which is also associated with the alteration process (Ba content is slightly higher when measured on a fresh fracture, c. 100 ppm).

The results of pXRF analysis on fresh fractures demonstrated that there is no clear correlation between chemical composition and samples of pottery with abradable and non-abradable surfaces. Only tendency to slightly lower contents of Ti and K in potsherds with non-abradable surfaces is observed, witch however is not confirmed by the results of chemical composition using WD-XRF.

Comparing the results of measurements by pXRF for individual samples does not reveal any regularities (besides lower Ti contents on fresh fracture surfaces). Levels of phosphorus (P) are also not consistently elevated on sherd surfaces. Figure 7 shows the differences in Ti, Fe, K and P concentrations on sherd surfaces in comparison with fresh fracture surfaces (the concentration of elements on fresh fractures was recalculated to 1).

Once the pXRF measurements had been completed nine samples were selected for detailed analysis (a full suite of analyses was not carried out on all of these samples). The selected samples (Fig. 8) are described below:

BES7 – indeterminate, medium-thick body sherd with smooth, plain, grey, abradable surface. Non-abradable fabric of uniform colour throughout. Sherd recovered from floor level of workshop.

BES22 – medium-thick bowl sherd with smooth surface and slightly everted rim featuring incised decoration. Fabric hard, non-abradable and grey throughout. Sherd recovered immediately next to kiln pit.

BES25 – base and lower body sherds of medium-thick-walled vessel with smooth, orange surface. Remnants of light brown slip on outer surface. Thick layer of brown slip on inner surface. Fabrics non-abradable and orange throughout. Sherds recovered from fill of kiln pit at point of connection to flue.

BES26 – medium-thick (0.5-1 cm) collared bowl sherd with smooth surfaces featuring incised decoration. Orange, slightly abradable sherd surface with grey

[11] For a list of results from five projects see: Daszkiewicz, Schneider 2018, in press.

slip. Non-abradable fabric with grey core and orange margins. Sherd recovered immediately next to kiln pit.

BES27 – medium-thick bowl or jug sherd with smooth surface. Partially abradable sherd (grey in colour) with patches of slip. Fabric non-abradable and grey throughout. Sherd recovered immediately next to kiln pit.

BES29 – medium-thick upper cup sherd with smooth surface decorated with burnished wavy lines. Grey sherd surface with patches of slip. Fabric non-abradable and grey throughout. Sherd recovered from floor level of workshop.

BES34 – upper bowl sherd with smooth surface decorated with circumferential applied strip. Dark brown, almost black, non-abradable sherd surface. Orange, slightly abradable fabric. Sherd recovered from fill of kiln pit.

BES37/38 – medium-thick upper bowl sherds with smooth surfaces. Partially abradable sherd (grey in colour) with black layer (non-abradable). Fabric non-abradable and grey throughout. Sherd recovered immediately next to kiln pit.

BES41 – medium-thick upper vessel sherd with smooth surface. Grey parts of sherd surface – abradable, black parts – non-abradable. Grey fabric with discernible black layer. Sherd recovered from plough-spoil in trench 2/98 (*c.* 10 m from kiln).

In view of the fact that the abrasion resistance of ceramic materials is dictated principally by their hardness and porosity (more porous materials are less resistant to abrasion), the hardness of selected samples was measured on the Mohs Hardness Scale (MHS) and their physical ceramic properties were assessed. A hardness test was carried out both to assess matrix hardness (i.e. the resistance offered by the matrix to external mechanical factors aiming to scratch its surface) and to assess surface hardness. Two tests were carried out on each of the analysed samples, gauging the hardness of a fresh fracture surface and of the sherd's outer surface. Further tests were also carried on three samples to assess the hardness of a cross-sectional surface.

The abradable outer surface of three sherds has a hardness of < 2 on the Mohs scale, whilst the abradable surface of one sherd (BES7) has a greater hardness of 2.5. Most of the sherd surfaces which are non-abradable have a hardness of 2.5 (only two samples have non-abradable surfaces with a hardness of 3.5: BES22 and the black part of BES41). Fresh fracture surfaces have a hardness of 2.5 or 3.5. Cross-sectional surfaces are slightly harder than those of fresh fractures. The maximum difference in hardness was noted for BES41: the cross-sectional surface and the black part of the sherd's outer surface have a hardness of 3.5, whilst the grey part of the sherd's outer surface has a hardness of < 2.

The analysed samples exhibit fairly varied values of open porosity, apparent density and water absorption[12] (Tab. 1). Sample BES22 has the lowest open

[12] Open porosity, water absorption and apparent density were estimated by hydrostatic weighing.

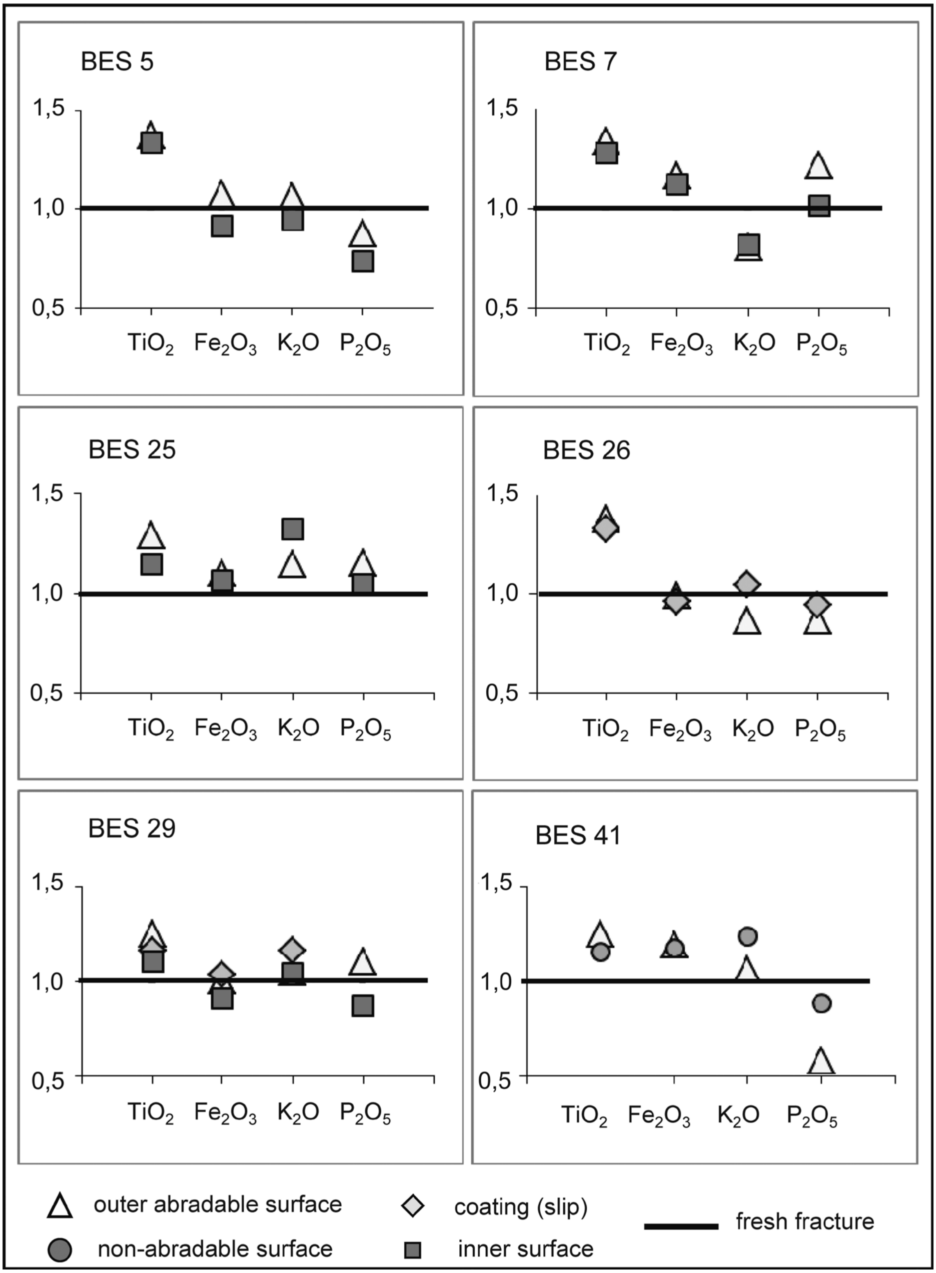


Fig. 7. Measurements by pXRF: Differences in Ti, Fe, K and P concentrations on sherd surfaces in comparison to fresh fracture surfaces (the concentration of elements on fresh fractures is calculated to 1)

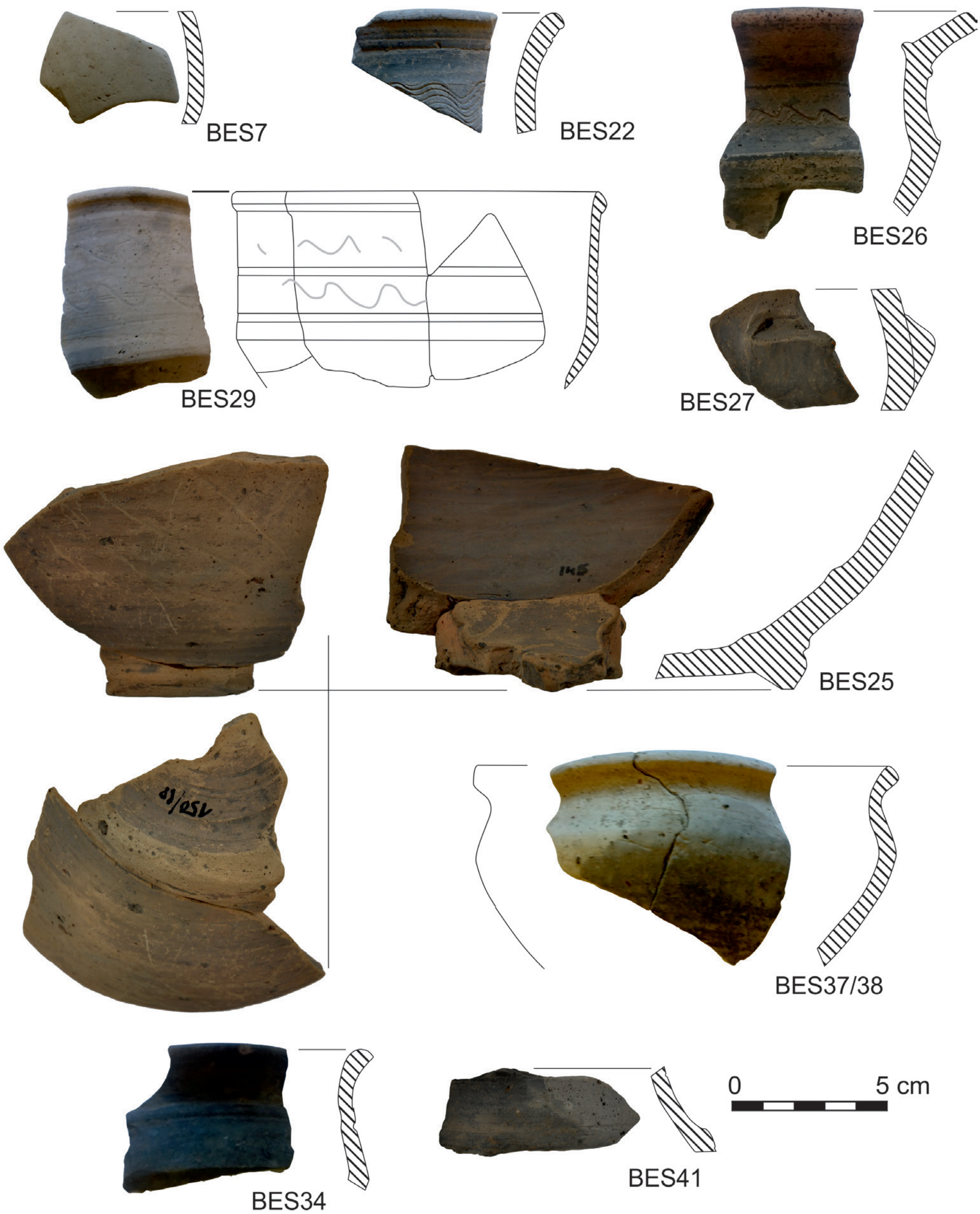


Fig. 8. Bessów, site 3: Samples selected for detailed analysis

Table 1. Physical ceramic properties (Po = open porosity, N = water absorption, dv = apparent density); Teq = equivalent original firing temperature; l.o.m. = loss of mass

Sample No.	Labor No.	Po [%]	N [%]	dv [g/cm³]	Teq	l.o.m. % 105-900°C
BES 7	MD6543	31.71	18.80	1.69	900-950°C	0.81
BES22	MD6590	16.68	7.84	2.13	*c.* 1000°c	0.39
BES25	MD6593	28.24	15.52	1.82	900-950°C	0.98
BES26	MD6592	23.13	12.68	1.82	900-950°C	0.71
BES27	MD6657				> 900°C	0.58
BES29	MD6531	33.06	19.53	1.69	950-1000°C	0.45
BES 34	MD6591				*c.* 750-800°C	3.85
BES 37/38	MD6658				*c.* 750-800°C	2.81
BES41	MD6659	27.84	16.09	1.73	800-850°C	0.89

porosity (16.7 vol.%) and the greatest hardness (the fresh fracture surface and the sherd's outer surface have a hardness of 3.5 on Mohs' scale). Two samples with abradable surfaces have an open porosity greater than 30 vol.%. Relatively high open porosity is not correlated, in case of analysed samples, with original firing at a low temperature, but most likely relates to the way in which the ceramic body was de-aired, the forming technique used and the presence of organic temper (natural not intentional temper). There is a correlation between sample hardness, the presence of slip and the open porosity value.

There is no correlation between hardness, open porosity and original firing temperature (Teq). Seven of the nine analysed sherds were fired at 900–1000°C. Only two sherds were fired at a lower temperature (*c.* 750-800°C)[13]. Figure 9 shows the results of K-H analysis[14] of two samples (BES7 with abradable surface and BES22 with non-abradable surface); these results clearly show that the sherds were fired at temperatures exceeding 900°C.

Figure 10 shows two samples before (original sample) and after refiring (MGR-analysis)[15]. The results of MGR-analysis demonstrate that the analysed samples were originally fired either at the optimal temperature for the given ceramic body

[13] Similar ranges of firing temperatures have been determined for pottery of the same period found at other sites (Wirska –Parachoniak 1985, Dobrzańska et al. 2006).

[14] Kilb-Hennike analysis; see e.g. Daszkiewicz 2014, Daszkiewicz, Schneider 2018, Daszkiewicz, Maritan 2017.

[15] Matrix Group by Refiring, see: Daszkiewicz, Schneider 2001, Daszkiewicz 2014, Daszkiewicz, Maritan 2017.

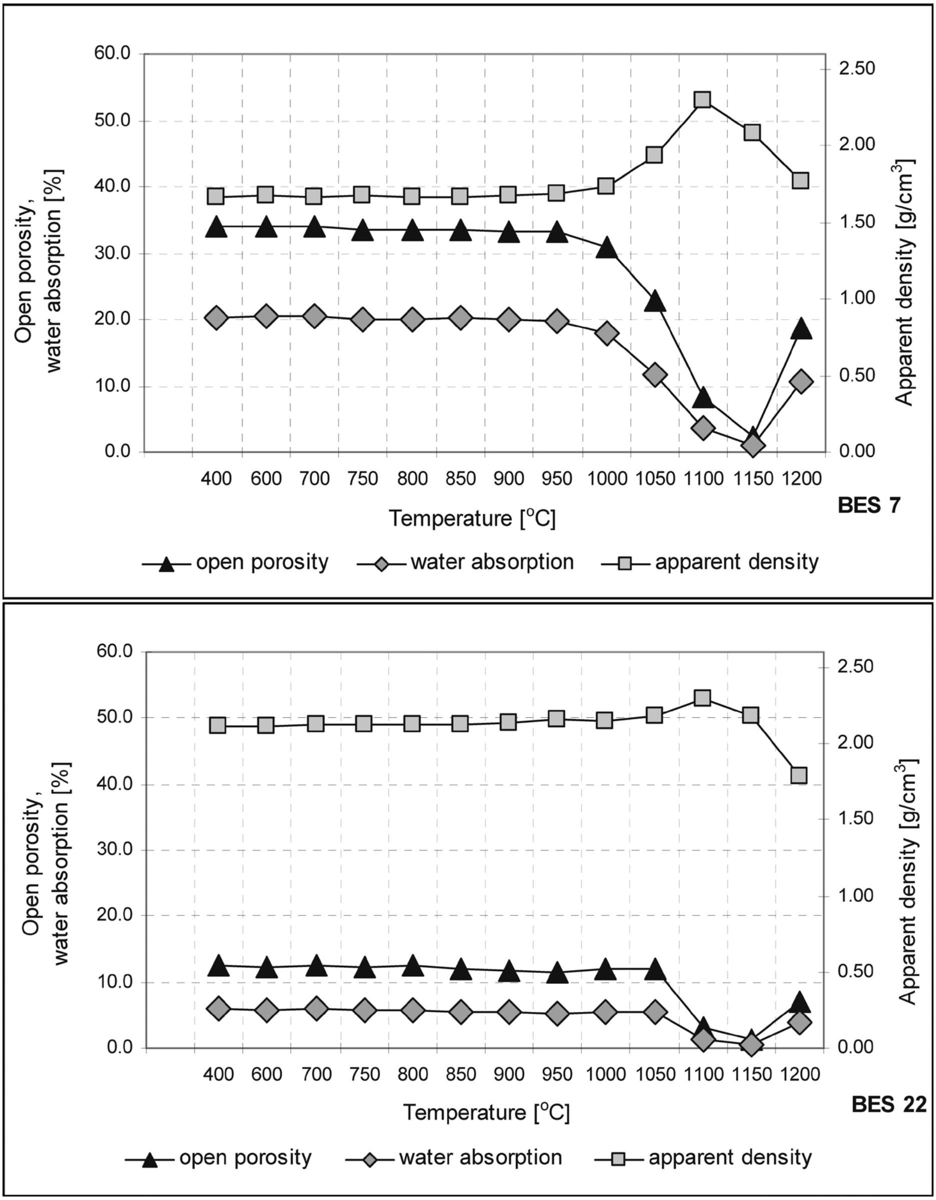


Fig. 9. Results of K-H analysis: BES 7 = pottery fragment with abradable surface; BES 22 = pottery fragment with non-abradable surface

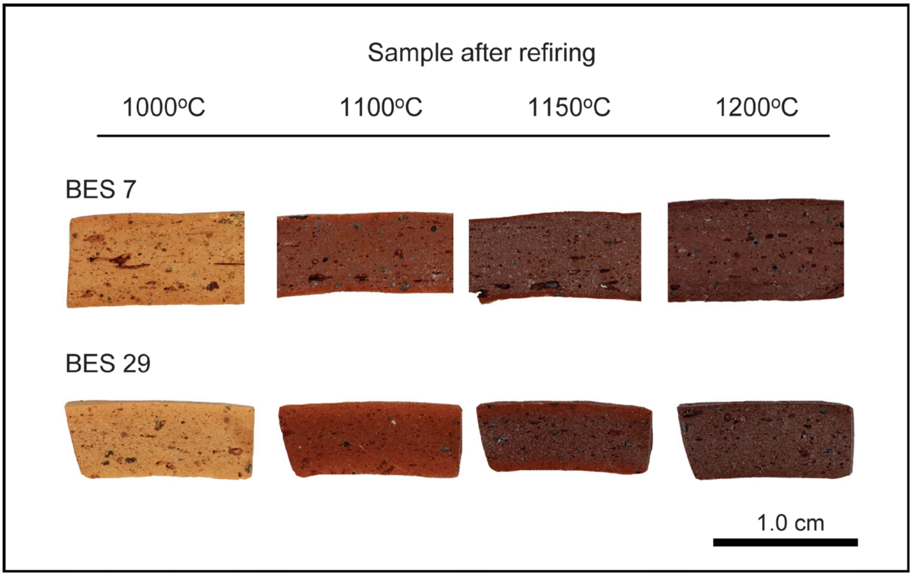


Fig. 10. Samples after refiring in air

(e.g. non-abradable BES29), or that pottery made from this type of ceramic body, like abradable BES7, should be fired at a slightly higher temperature in order to consolidate the ceramic material. It should be stressed that none of the analysed samples could have been fired at a temperature much higher than 1000°C (max. 1100°C) regardless of firing atmosphere.

TG-DTG-DTA analysis results for grey sherds BES7 and BES29 show that the curves do not exhibit thermal effects characteristic of clay minerals nor exothermic peaks above 900°C. Losses in mass up to 100°C combined with endothermic peaks are associated with the loss of moisture. Exothermic peaks combined with losses in mass observed in the temperature range up to 400°C (with a very slight dip in the TG curve) evidence the burning out of a small amount of organic matter (loss in mass 200-600°C is ≤ 0.8 %[16]). In addition to the endothermic peak associated with polymorphic quartz transformation, an iron-oxidisation related exothermic peak associated with a gain in mass (0.12%) was also observed. The iron oxidisation effect combined with a small loss in mass in the temperature range associated with the burning out of organic matter indicates that the original firing was carried out in a reducing atmosphere.

[16] Loss in mass in BES samples is significantly lower than estimated for a similar type of pottery by Dobrzańska et all. 2006.

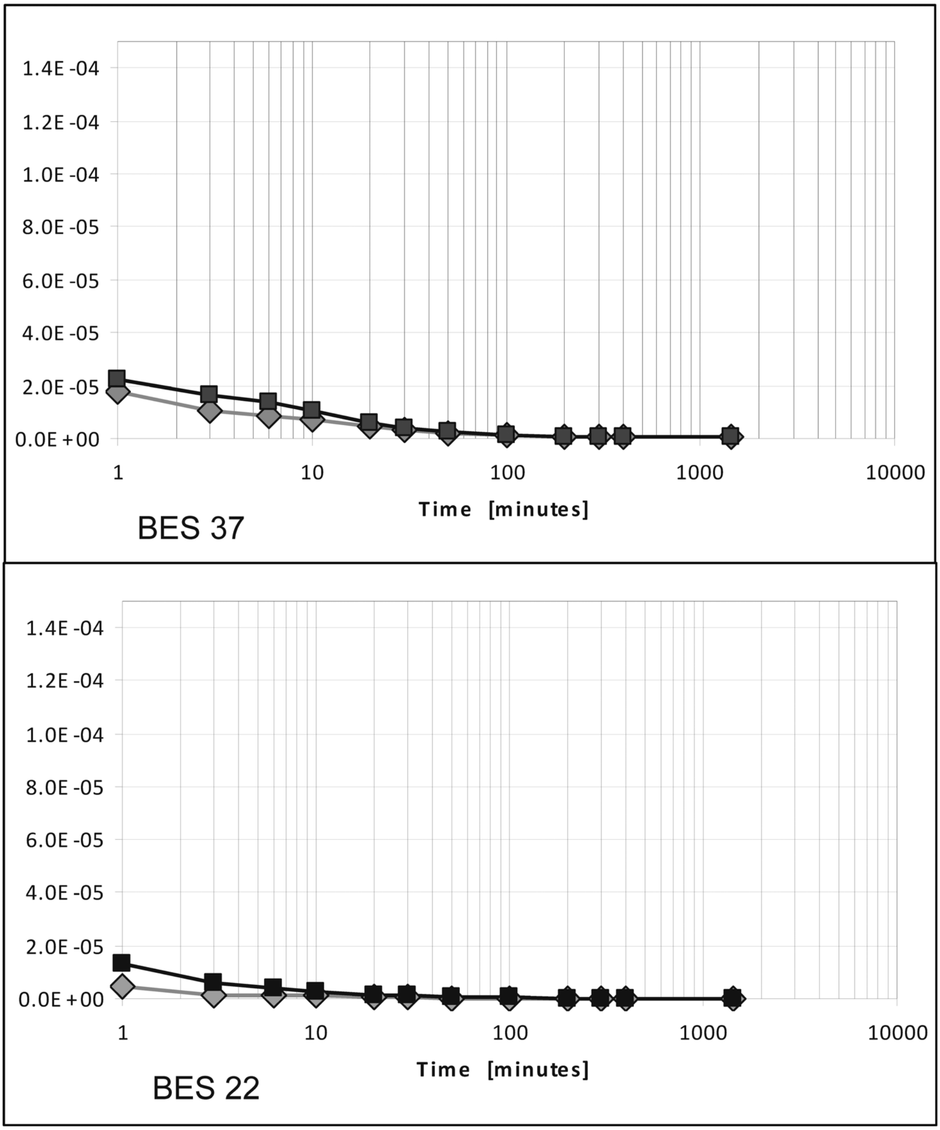


Fig. 11. Results of functional properties analysis. Y-axis: water permeability, cm3/cm2s; gray diamonds = first measurements (original samples, only boiled in distilled water); black squares = second measurement (samples heated at 400°C)

µXRD analysis[17] of grey sherds revealed the presence of hercynite, and some maghemite and magnetite.

In this case, analysis of functional properties was limited to gauging water permeability[18], which revealed that the samples were impermeable, including those with abradable surfaces (BES37, Fig. 11). Measurements were performed twice on original samples and on samples heated at 400°C. The difference in permeability is minimal which indicates that there was no impregnation affect, or in other words differences in permeability attributable to the burning out of organic matter within the open pores (intentional impregnation or the effect of the vessels having been used).

In order to assess the properties of the coating on the surface of some of the vessels, µXRD analysis was carried out on one of the samples. This sample in question was BES26, an orange sherd with a slightly abradable surface featuring large patches of a black surface coating. Viewed in cross-section, the fabric of this sherd has a grey core and orange margins. Analysis revealed the presence of maghemite, magnetite and hercynite both in the black coating and in the sherd itself; there are more feldspars in the coating, whilst hematite is present in the sherd.

The surfaces of two other samples (BES41, BES29) which also featured an extant black coating were subjected to MGR-analysis. In the case of the BES41 sample this analysis revealed a marked difference in thermal behaviour between the abradable surface and the black layer (Fig. 12 - the black layer has a different thermal expansion). SEM-EDS analysis showed that the layer on top of the black coating (Fig. 13, measured spot 1297) had high concentrations of C (Cu-sputtered samples)[19] and higher concentration of Na in contrast to the layers below (Fig. 13, measured spots 1295 and 1296). Black layer (1295) had a higher concentration of Fe, K, and P; its differs significantly from the composition of the sherd (1296). Ash particles were observed in the black layer

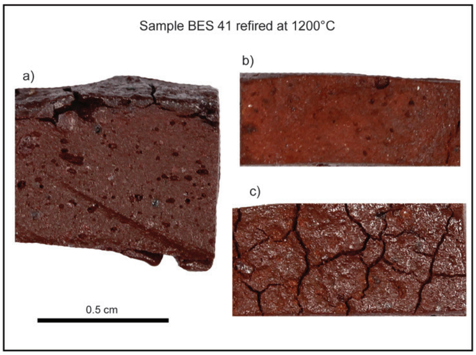
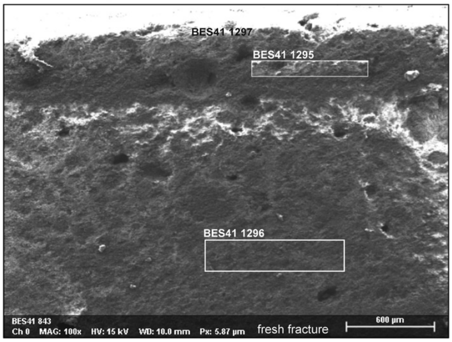


Fig. 12. Sample BES 41 after refiring at 1200°C: cross-section (a), abradable gray surface (b) and black coating (c)

[17] The authors would like to thank Christoph Berthold from the Competence Center Archaeometry – Baden-Wuerttemberg (CCA-BW), Universität Tübingen, for his kindness and for performing this analysis.

[18] For a description of the method used see: Daszkiewicz, Raabe 1996, Daszkiewicz et al. 2006

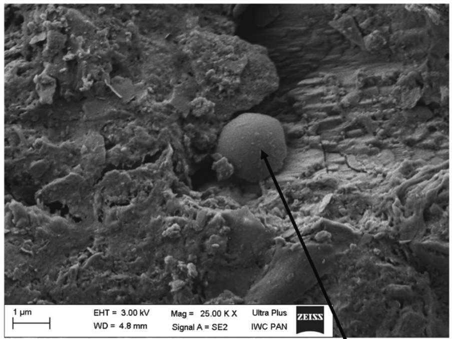
[19] SEM/EDX analysis was carried out in Institute of High Pressure Physics of the Polish Academy of Sciences.



Data normalised without C, wt.%

	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	SrO	ZrO_2	SO_3	Cl	C
BES41 1297	56.05	1.15	17.62	4.977	0.05	2.76	1.79	2.62	2.64	5.13	2.04	0.82	1.07	1.28	25.09
BES41 1295	52.14	1.27	19.32	10.61	0.05	1.81	1.5	0.76	4.03	5.03	2.02	0.51	0.56	0.39	6.99
BES41 1296	62.49	1.11	19.15	6.08	0.02	1.55	0.96	0.14	3.54	1.1	2.31	0.75	0.47	0.31	5.72

Fig. 13. SEM image with measured spots, Cu-sputtered samples; below the results of analysis normalised without C



SiO_2	TiO_2	Al_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	SO_3	Cl
66.08	0.14	14.25	4.38	0.05	1.60	1.02	4.41	5.51	1.76	0.32	0.48

[in wt.%]

Fig. 14. SEM image, Cu-sputtered samples; ash particles observed in the black non-abradable layer

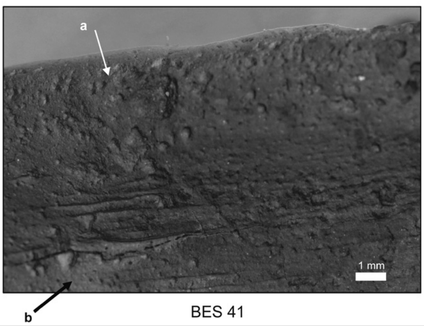


Fig. 15. RTI-image of weathered black non-abradable layer (a) and grey abradable layer (b).

(Fig. 14). The results indicate that the sherd was coated with a black layer (probably slip rather than gloss) with a higher content of fluxes, the surface of which was then smoked. The black slip did not survive across the whole surface of the sherd because of alteration processes (Fig. 15). For sample BES 41 the conclusions drawn from SEM-EDS analysis agree with the conclusions drawn from the results of pXRF measurements concerning the relation of Ti, Fe and K content measured on fresh fracture and on surfaces.

The second sample (BES29) with a partially extant black layer exhibited a different thermal behaviour: the outer layers are sintered whilst the middle of the sample is slightly over-melted. SEM-EDS analysis did not reveal any compositional differences between the abradable and the black non-abradable parts (the same was found in measurements by pXRF).

The results of chemical anlysis by WD-XRF (Tab. 2) and MGR-analysis revealed that the pottery found in Bessów was made of illitic-kaolinitic clay coloured by iron compounds. The presence of clay minerals results from the chemical composition. Calculation of the rational composition[20] shows that the ceramic body contains 50% quartz, 30% illite and 20% kaolinite (CaO content by WD-XRF is below 1 wt.%). Two major chemical groups can be identified (Tab. 2): the group which most probably represents local wares (both abradable and non-abradable sherds) and one outlier (sample BES 26). Subgroups of the major group are not correlated with the

Table. 2. Results of chemical analysis by WD-XRF. Major elements are calculated as oxides and normalised to a constant sum of 100%. The element concentrations determined are valid for samples ignited at 900°C (specimens for the measurement are melted after ignition). Preparation of samples for analysis carried out in ARCHEA dr Małgorzata Daszkiewicz, Warsaw, measurements using a PANnalytical AXIOS XRF-spectrometer and the calibration of Arbeitsgruppe Archaeometrie by G. Schneider (measurements by courtesy of Anja Schleicher, Helmholtz-Zentrum Potsdam, Deutsches GeoForschungsZentrum GFZ, Sektion 4.2, Anorganische und Isotopengeochemie)

a)

Sample No.	Lab. No.	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5
		per cent by weight									
BES 26	outlier MD6592	63.29	0.960	19.65	9.43	0.158	1.94	0.77	0.51	2.90	0.40
BES 41	MD6659	66. 10	0.935	18. 36	7.44	0.115	1.82	0.62	0.72	3.21	0.67
BES 27	MD6657	66.84	0.935	18.20	7.38	0.130	1.88	0.63	0.69	3 02	0.29
BES 34	MD6591	66. 13	0.927	18. 15	7.87	0.143	1.70	0.67	0.83	2.66	0.93
BES 7	MD6543	66. 65	0.961	18. 19	7.60	0.157	1.87	0.63	0.70	2.82	0.43
BES 22	MD6590	67.89	0.917	17.35	7.36	0.203	1.82	0.66	0.81	2.72	0.27
BES 37/38	MD6658	64. 96	0.964	18. 08	7.54	0.128	1.51	0.72	0.77	2.55	2.77
BES 29	MD6532	69.44	0.939	17. 17	6.25	0.123	1.75	0.56	0.81	2.75	0.21
BES 25	MD6593	69.21	0.934	17. 31	5.98	0.044	1.81	0.65	0.80	3.00	0.28
clay	MD6544	74.77	0.739	12.36	4.68	0.099	1.57	2.30	1.01	2.33	0.15
clay	MD6545	73. 28	0.779	13. 06	5.16	0.131	1.66	2.28	1.07	2.42	0.16

cont. Tab. 2

[20] Calculation of rational composition of ancient ceramics – see Daszkiewicz, Schneider, Analysis of archaeological ceramics 2018

cont. Table 2.

b)

Lab. No.	V ppm	Cr	Ni	(Cu)	Zn	Rb	Sr	Y	Zr	(Nb)	Ba	(La	Ce)	Al_2O_3/ SiO_2	Zr/ SiO_2
outlier MD6592	162	162	94	43	149	177	105	47	177	17	619	51	87	0. 31	2.80
MD6659	152	153	73	30	120	152	93	43	209	19	594	53	99	0.28	3.16
MD6657	144	148	76	19	114	154	99	43	222	19	550	46	83	0. 27	3.31
MD6591	139	152	100	27	147	142	108	36	224	19	746	34	71	0.27	3.38
MD6543	147	153	79	25	122	147	97	42	224	18	530	37	88	0.27	3.36
MD6590	143	143	76	25	106	143	102	44	230	17	538	51	81	0. 26	3.38
MD6658	139	151	76	26	117	120	158	42	230	19	905	41	69	0.28	3.54
MD6532	134	145	75	176	105	140	94	39	247	19	537	38	63	0. 25	3.56
MD6593	126	150	75	35	115	153	102	45	255	17	555	47	79	0.25	3.69
MD6544	93	120	56	26	105	109	115	28	317	16	415	29	53	0.17	4.24
MD6545	95	125	63	29	124	116	115	32	332	16	411	23	63	0.18	4.53

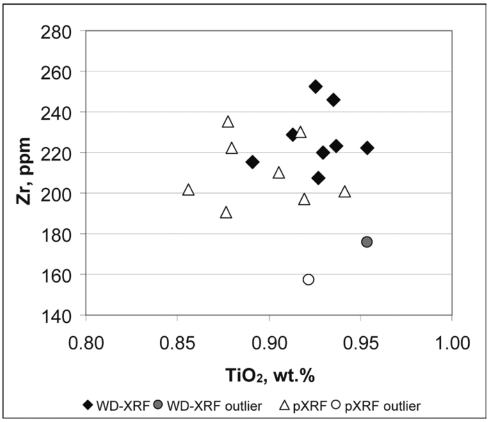


Fig. 16. Ti vs. Zr, results of chemical analysis by WD-XRF and pXRF

properties of sample's surfaces. Sample BES 37/38 is the only sample analysed by WD-XRF which, despite having its outer layer removed for analysis, has a high P_2O_5 content and a higher concentration of Ba than the other sherds (Tab. 2). This is attributable to post-depositional processes. The outlier sample BES26 is obvious in results of pXRF and of WD-XRF (Fig. 16) but the data of pXRF and WD-XRF are shifted against each other.

Two clays sampled from the vicinity of the site were also analysed (Fig. 1). They contain too much CaO (very fine grains, homogenously distributed) and too little Fe_2O_3 (Tab. 2) in comparison to the analysed ceramic sherds. These local clays fired in reducing atmosphere only pale grey because of low iron contents (Fig. 17). All of the fired specimens have

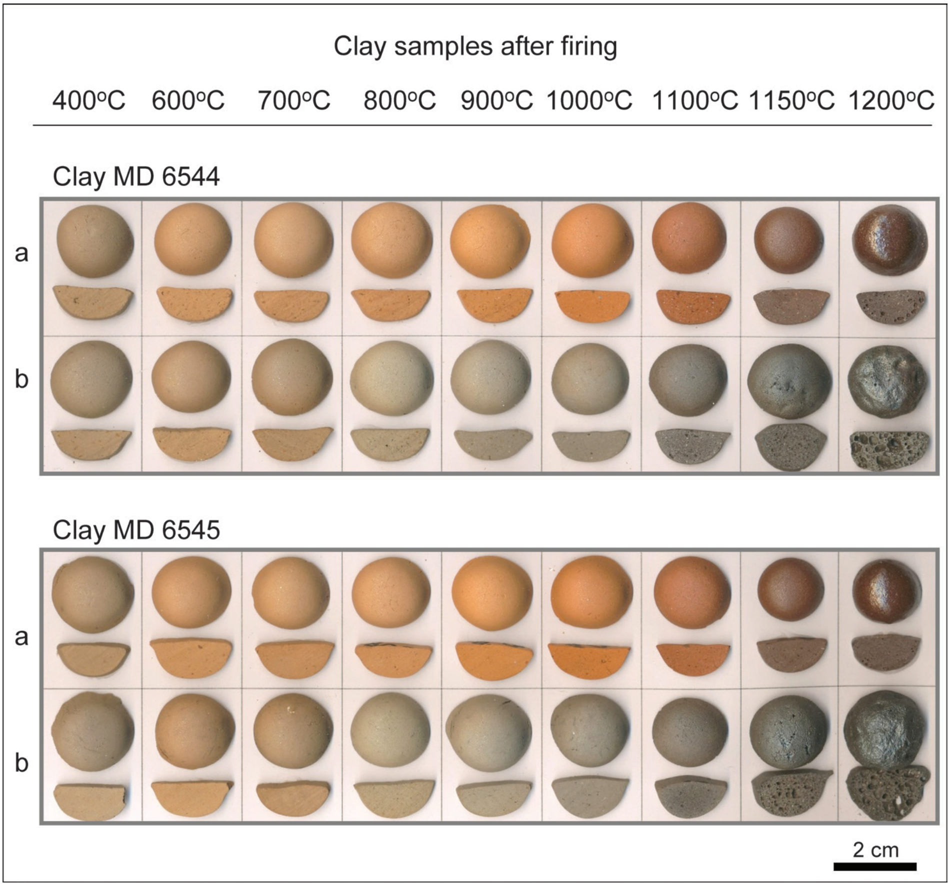


Fig. 17. Firing test of two local clay samples

no abradable surface at any of the firing temperatures[21]. A very big, unexpected, difference was observed in thermal behaviour connected with firing atmosphere (Fig. 17). Fundamental differences in open porosity between clay samples fired in an oxidising atmosphere and those fired in a reducing atmosphere did not become apparent until they were fired at 1100°C (Tab. 3). The open porosity values of briquettes made in the laboratory are much higher than the open porosity values of the analysed sherds, which is attributable both to the raw material and the technology used (de-airing of the ceramic body and forming technique).

[21] Various kaolinitic clays analysed by the authors with iron contents below 4% are characterised by abradability, evident in firing tests up to and including a temperature of 1100°C.

Table 3. Physical ceramic properties of fired clay samples (Po = open porosity, N = water absorption, dv = apparent density)

Sample	Firing temp.	Firing atosphere					
		oxidizing			reducing		
		Po %	N %	dv g/cm^3	Po %	N %	dv g/cm^3
MD 6544	700	35.8	21.0	1.70	35.0	20.2	1.74
	800	37.4	22.6	1.65	38.0	23.1	1.65
	900	37.4	22.8	1.64	39.3	24.0	1.63
	1000	36.3	21.3	1.71	35.8	20.8	1.72
	1100	31.2	17.2	1.81	23.1	13.4	1.73
	1150	4.8	2.1	2.28	29.2	20.4	1.43
	1200	2.2	1.1	2.01	21.4	21.9	0.98
MD 6545	700	35.9	21.3	1.68	36.6	21.9	1.67
	800	38.1	23.4	1.63	38.3	23.4	1.64
	900	36.9	22.7	1.63	38.8	23.7	1.64
	1000	37.4	22.7	1.65	36.8	21.8	1.69
	1100	29.2	15.8	1.85	24.0	14.3	1.67
	1150	2.1	0.9	2.27	32.7	24.8	1.32
	1200	1.4	0.7	1.99	29.0	26.4	1.10

IV. CONCLUSIONS

The results of archaeometric analysis of pottery from Bessów did not substantiate the hypothesis that the alteration process is responsible for the abradability of pottery surfaces not coated with a non-abradable layer. There is no doubt that abradability is not attributable to the alteration effect in any of the analysed samples with abradable surfaces.

Laboratory analysis revealed that the abradability of the examined pottery was linked to the technology used in its production. Vessels were fired at temperatures appropriate for biscuit-firing and their surfaces were black-coated, probably with a coating of the black-gloss variety (it would be advisable to analyse a greater number of samples). The black coating prevented the surface from being abradable and gave vessels a surface sheen. Notably, the black coating did not affect the pottery's functional properties (the pottery was impermeable both with and without the surface coating). The technology used in making pottery from Bessów differs to that used in the production of pottery from Sanok as well as Chabielice and Moszczenica (different raw material, different firing temperature and firing atmosphere, different surface coatings).

The pottery's abradability results from post-depositional processes (alteration effects) but not as usually understood. The alteration effect is not responsible for the abradability of the pottery surface but for damaging the slip (!) which then renders the sherd abradable.

Should this alternative type of technology be linked to outside cultural influences? A study of vessel forms has shown that there are no analogies with pottery from the Dacian cultural sphere. However, numerous analogies of forms from the Bessów settlement are found at the Przeworsk culture sites (Dobrzańska 2015, 402-404; Okońska, 2018). These conclusions are significant because they clearly indicate that settlement sites along the lower Raba are attributable to the Przeworsk culture.

There are also no grounds for treating assemblages of Pakoszówka-Bessów type pottery as a cultural phenomenon. The same conclusions were suggested by Halina Dobrzańska on the basis of analysis results from sites in other regions (Dobrzańska et al. 2004; Dobrzańska 2015, 404). Having said that, this term can, however, be used in reference to Younger and Late Roman period wheel-made ceramics with specific technological features, regardless of their cultural attribution.

The particular technology used to produce wheel-made ceramics with abradable surfaces covered with a non-abradable coating to make them fully functional (the slip did not affect a vessel's permeability, but merely prevented its surface from abrading easily), has been confirmed at multiple sites in two different regions (along the upper San and the lower Raba) and does not represent defective technology but merely technology. During its useful life this easily abradable pottery would not have been abradable. We cannot say whether this was a sought-after or preferred variety of pottery given that it required additional treatment and had to be fired at a higher temperature than other wares[22]; however, there is no doubt that the technology used to make it was effective and that the vessels it produced were fully functional.

The functional properties of this type of pottery, the fact that it is highly impermeable, and the way in which it was fired (its uniform reduction and the temperatures attained during firing - at least in the case of the analysed sherds from Bessów) suggest that it was produced by specialist potters. This is indirectly corroborated by the variety of forms and decorative motifs seen on pottery from the

[22] This may have been why kilns of various construction were built at the Strzelce Małe production site, though further analysis is required, in particular to determine the firing temperature of pottery from this site.

lower Raba region (Kordecki, Okoński 1999, Fig. 3-5, 10-12, 19-21; Okoński 1999-2000, Fig. 6-13, 18-25, 28, 29). It is worth highlighting that this sort of pottery does not only occur at peripheral production sites, as suggested by Dobrzańska (2004, 687). It has also been recorded at production sites in Beregsurány, Medieşu Aurit and Strzelce Małe, where it was found alongside high quality 'non-abradable' pottery (also recovered from the fill of pottery kilns).

Further research is required into the presence of abradable pottery at sites along the upper San, where vessels with this kind of surface come in forms for which there are numerous analogies among the pottery noted in areas inhabited by Dacian tribes (Madyda-Legutko 1996, 76-77; Madyda-Legutko, Pohorska-Kleja 2004; Madyda-Legutko *el al.* 2004, 2008). Although the abradability of pottery in those regions may also be attributable to local clay deposits (Dobrzańska et al. 2004, 678-688), its forms clearly point to influences from neighbouring cultural areas.

REFERENCES

Bohr M.
2015 *Osada kultury przeworskiej i ślady działań z okresu I wojny światowej w Nienowicach, stan. 17, pow. jarosławski, woj. podkarpackie,* [in:] *Raport 10*, S. Kadrow (ed.), Warsaw, p. 187–217.

Cetera A., Okoński J.
1994 *Materiały do pradziejów prawobrzeża dolnego biegu Raby*, Rocznik Bocheński II, p. 5–53.

Daszkiewicz M.
2014 *Ancient pottery in the laboratory – principles of archaeological investigations of provenance and technology,* Novensia 25, p. 177–197.

Daszkiewicz M., Bobryk E., Schneider G.
2006 *Neuassyrische Kochtopfkeramik vom Roten Haus: chemisch-mineralogische Zusammensetzung und Funktionseigenschaften*, [in:] *Die Keramik des „Roten Hauses" von Tall Schech Hamad/Dur Katlimmu, Berichte der Ausgrabung Tall Schech Hamad/Dur Katlimmu (BATSH) 7,* F.J. Kreppner (ed.), p. 421–437.

Daszkiewicz M., Maritan L.
2017 *Experimental Firing and Re-firing*, [in:] *The Oxford handbook of archaeological Ceramic Analysis,* A. Hunt (ed.), Oxford, p. 487–508.

Daszkiewisz M., Okońska M., Bobryk E.
2018 *Defective technology or alteration effect? The case of Pakoszówka-Bessów type pottery (Bessów, south Poland),* [in:] *Archäometrie und Denkmalpflege*, L. Glaser (ed.), Hamburg, p. 50–53.

Daszkiewicz M., Raabe J.
1996 *Zastosowanie pomiaru przesiąkliwości wodnej w badaniach ceramiki zabytkowej (Application of water permeability measurements in the study of ancient ceramics),* Ceramics 50 (Polish Ceramic Bulletin 12, Polish Academy of Science Krakow Division Papers of the Commission on Ceramic Science, Polish Ceramic Society), p. 235–238.

Daszkiewicz M., Schneider G.
2001 *Klassifizierung von Keramik durch Nachbrennen von Scherben,* Zeitschrift für schweizerische Archäologie und Kunstgeschichte 58, p. 25–32.
2018 *Guide for Using pXRF for Chemical Analysis of Archaeological Pottery,* [in:] *Approaaching Economic Spaces, Methods and Interpretation in Archaeometric Ceramic Analysis* (ed. Michael Meyer), 2018 Edition Topoi/Exzellenzcluster Topoi der FU Berlin und der HU zu Berlin, in press

Daszkiewicz M., Schneider G. (with contribution of Bobryk E.)
2018 *Analysis of archaeological ceramics,* [in:] *Approaaching Economic Spaces, Methods and Interpretation in Archaeometric Ceramic Analysis* (ed. Michael Meyer), 2018 Edition Topoi/Exzellenzcluster Topoi der FU Berlin und der HU zu Berlin, in press.

Dobrzańska H.
1980 *Zagadnienie datowania ceramiki toczonej w kulturze przeworskiej,* Archeologia Polski 24/1, p. 87–152.
1990 *Osada z późnego okresu rzymskiego w Igołomi, woj. krakowskie, część II,* Polska Akademia Nauk, Instytut Historii Kultury Materialnej, Kraków.
2015 *Ośrodki wytwórczości ceramiki kultury przeworskiej w dolinie Wisły, na wschód od Krakowa oraz nad Rabą w kontekście geograficznym i kulturowym,* [in:] *Barbari superiores et inferiores. Archeologia Barbarzyńców 2014. Procesy integracji środkowoeuropejskiego Barbaricum*, L. Tyszler, E. Droberjar (eds.), Instytut Archeologii Uniwersytetu Łódzkiego, Muzeum Ziemi Wieluńskiej w Wieluniu, Stowarzyszenie Naukowe Archeologów Polskich Oddział w Łodzi, Łódź-Wieluń, p. 389–407.

Dobrzańska H., Kielski A., Wodnicka K.
2004 *Ścieralność ceramiki „siwej" – zjawisko kulturowe czy technologiczne?,* [in:] *Okres lateński i rzymski w Karpatach polskich,* J. Gancarski (ed.), Krosno, p. 679–690.
2006 *Archeologiczna ceramika „siwa" na przykładzie Zofipola*, Materiały Ceramiczne, 1/2006, p. 35–39.

Godłowski K.
1977 *Materiały do poznania kultury przeworskiej na Górnym Śląsku, cz. II*, Materiały Starożytne i Wczesnośredniowieczne 4, p. 7–237.

Jamka R.
1939/1948 *Ceramika siwa w świetle zespołów grobowych odkrytych na obszarze Polski środkowej, południowej i zachodniej*, Wiadomości Archeologiczne 16, p. 201–210.

Kordecki J., Okoński J.
1999 *Mikroregion osadniczy na prawobrzeżu dolnego biegu Raby,* [in:] *Na granicach antycznego świata. Sytuacja kulturowa w południowo-wschodniej Polsce i regionach sąsiednich w młodszym okresie przedrzymskim i okresie rzymskim. Materiały z konferencji, Rzeszów, 20-21 XI 1997*, S. Czopek, A. Kokowski (eds.), Rzeszów, p. 181–254.
2001 *Piece garncarskie z osady na stanowisku 13 w Strzelcach Małych, gmina Szczurowa,* Rocznik Bocheński V, p. 277–309.

Kozak D.N.
1999 *Osoblivosti etničonï istorii schodniokarpatskogo region v latenskij čas peršich stolittjach nošoï eri*, Etnogenez ta etniča istorija naselennja ukraïnskich Karpat 1, L'viv, p. 163–226.

Madyda-Legutko R.
1996 *Zróżnicowanie kulturowe polskiej strefy beskidzkiej w okresie lateńskim i rzymskim,* Uniwersytet Jagielloński, Rozprawy Habilitacyjne, nr 304/1, Kraków.

2004 *Polskie Karpaty w okresie późnolateńskim i w okresie wpływów rzymskich. Uwagi dotyczące zróżnicowania kulturowego*, [in:] *Okres lateński i rzymski w Karpatach polskich,* J. Gancarski (ed.), Krosno, p. 71–92.
2010 *Zróżnicowanie regionalne ceramiki wykonanej na kole garncarskim na przykładzie materiałów zabytkowych pochodzących z polskich Karpat*, [in:] *Ceramika rzemieślnicza jako źródło do badań nad zróżnicowaniem garncarstwa kultury przeworskiej*, H. Machajewski, B. Jurkiewicz (eds.), Pułtusk, Uniwersytet Gdański, Akademia Humanistyczna im. Aleksandra Gieysztora, p. 17–33.
2011 *Drehscheibenkeramik aus dem Gebiet polnischen Karpaten. Zur regionalen Differenzierung,* [in:] J. Bemmann, M. Hegewisch, M. Meyer, M. Schmauder (eds.), *Drehscheibentöpferei im Barbaricum - Technologietransfer und Professionalisierung eines Handwerks am Rande des Römischen Imperiums*, Bonn: Inst. für Vor- und Frühgeschichtliche Archäologie der Rheinischen Friedrich-Wilhelms-Univ. Bonn, p. 295–306.

Madyda-Legutko R., Pohorska-Kleja E.
2004 *Pakoszówka, Gde. Sanok, Woiw. Podkarpackie, FSt. 26 (eine Siedlung der jüngen römischen Kaiserzeit)*, Recherches Archéologiques de 1993-1998, p. 126–132.

Madyda-Legutko R., Pohorska-Kleja E., Rodzińska-Nowak J.
2004 *Warsztat garncarski z Sanoka, stan. 54, na tle materiałów ceramicznych z terenu górnego dorzecza Sanu,* [in:] *Okres lateński i rzymski w Karpatach polskich,* J. Gancarski (ed.), Krosno, p. 691–707.
2006 *Osada z okresu rzymskiego w Pakoszówce, stan. 1, pow. Sanok*, Rocznik Przemyski XLII: 6, z. 2, Archeologia, p. 69–83.
2008 *Ceramika z warsztatu garncarskiego z Sanoka, stan. 54, na tle materiałów ceramicznych z terenu górnego dorzecza Sanu. Próba interpretacji,* [in:] *Ceramika warsztatowa w środkowoeuropejskim Barbaricum,* A. Błażejewski (ed.), Wrocław: Instytut Archeologii Uniwersytetu Wrocławskiego, p. 9–23.

Okońska M.
2018 *The case-study of the so-called "pottery depot" from Bessów, site 3, commune Bochnia, Małopolska Province. Archaeological material and re-interpretation of the function,* Recherches Archéologiques Nouvelle Serie, 9, p. 349–377.

Okoński J.
1996 *Mikroregion osadniczy kultury przeworskiej na prawobrzeżu dolnego biegu Raby. Sprawozdanie z badań w 1995 roku,* Rocznik Bocheński IV, p. 333–353.
1999–2000 *Osada na stanowisku 3 w Bessowie, gm. Bochnia, na tle nadrabskiego mikroregionu osadniczego,* Acta Archaeologica Carpathica 35, p. 113–197.
2001 *Strzelce Małe, gm. Szczurowa, pow. Brzeski, woj. małopolskie. Stanowisko 13 (AZP 101-62: 42). Ratownicze badania wykopaliskowe w 2000 roku. Dokumentacja badań archeologicznych,* Tarnów. Archive of Wojewódzki Urząd Konserwacji Zabytków w Krakowie, Delegatura w Tarnowie (typesrcipt).

Okoński J., Szpunar B., Szpunar A.
2000 *Wyniki nadzoru archeologicznego na stanowisku 3 w Bessowie, gm. Bochnia, woj. małopolskie*, Materiały i Sprawozdania Rzeszowskiego Ośrodka Archeologicznego 21, p. 249–270.

Przychodni A.
1999–2000 *Analiza fragmentu terra sigillata z osady na stanowisku 3 w Bessowie, gm. Bochnia, woj. Małopolskie,* Acta Archaeologica Carpathica 35, p. 196–172.

Rodak J.
2010 *Osada kultury przeworskiej na stanowisku 9 w Krakowie-Kurdwanowie (opracowanie wstępne),* Instytyt Archeologii i Etnologii PAN, Muzeum Archeologiczne w Krakowie i Uniwersytet Jagielloński – Krakowski Zespół do Badań Autostrad, http://docplayer.pl/15319137-Osada-kultury-przeworskiej-na-stanowisku-9-w-krakowie-kurdwanowie-opracowanie-wstepne-justyna-rodak.html, access: 28.07.2018.

Rodzińska-Nowak J.
2006 *Jakuszowice, stanowisko 2. Ceramika z osady kultury przeworskiej z młodszego i późnego okresu wpływów rzymskich i wczesnej fazy okresu wędrówek ludów*, Zeszyty Naukowe Uniwersytetu Jagiellońskiego, Prace Archeologiczne, vol. 61, Kraków.
2010 *Uwagi o chronologii ceramiki wykonanej na kole garncarskim w kulturze przeworskiej w świetle analizy materiałów zabytkowych z osady w Jakuszowicach, woj. świętokrzyskie, i cmentarzyska w Opatowie, woj. śląskie,* [in:] *Ceramika rzemieślnicza jako źródło do badań nad zróżnicowaniem garncarstwa kultury przeworskiej*, H. Machajewski, B. Jurkiewicz (eds.), Pułtusk, Uniwersytet Gdański, Akademia Humanistyczna im. Aleksandra Gieysztora, p. 71–86.
2011 *Zur Chronologie der Drehscheibenkeramik in der Przeworsk-Kultur im Lichte der jüngsten Forschungsergebnisse,* [in:] J. Bemmann, M. Hegewisch, M. Meyer, M. Schmauder (eds.), *Drehscheibentöpferei im Barbaricum - Technologietransfer und Professionalisierung eines Handwerks am Rande des Römischen Imperiums*, Bonn: Inst. für Vor- und Frühgeschichtliche Archäologie der Rheinischen Friedrich-Wilhelms-Univ. Bonn, p. 285–294.
2018 *Some remarks on the genesis of wheel-made pottery in the Przeworsk Culture,* [in:] M. L. Nagy, K. L. Szőlősi (eds.), *To make a fairy's whistle from a briar rose. Studies presented to Eszter Istvánovitson her sixtieth birthday*, Jósa András Múzeum, Nyíregyháza, p. 313–323.

Schneider G.
2017 *Mineralogical and chemical alteration*, [in:] *The Oxford handbook of archaeological Ceramic Analysis,* A. Hunt (ed.), Oxford University Press, p. 162–180.

Stobierska E., Wyszomirski P., Gaweł P.
2008 *Aneks. Badania ceramiczne i mineralogiczne ceramiki z Sanoka i Pakoszówki*, [in:] *Ceramika warsztatowa w środkowoeuropejskim Barbaricum*, A. Błażejewski (ed.), Wrocław: Instytut Archeologii Uniwersytetu Wrocławskiego, p. 25–35.

Szpunar A., Okoński J.
2004 Tarnowiec, gm. Tarnów, woj. małopolskie. Osada z okresu rzymskiego, [in:] *Okres lateński i rzymski w Karpatach polskich,* J. Gancarski (ed.), Krosno: Muzeum Podkarpackie w Krośnie, p. 471–541.

Szpunar B., Szpunar A.
2004 Osada z okresu rzymskiego w Koszycach Wielkich, gm. Tarnów, stan. 5, [in:] *Okres lateński i rzymski w Karpatach polskich,* J. Gancarski (ed.), Krosno: Muzeum Podkarpackie w Krośnie, p. 543–571.

Wirska-Parachoniak, M.
1985 *Technologia produkcji późnorzymskiej ceramiki toczonej z dorzecza górnej Wisły*, Acta Archaeologica Carpathica 24, p. 169–219.

Addresses of the Authors

Magdalena Okońska
Institute of Archaeology
Jagiellonian University in Cracow
ul. Gołębia 11
31-007 Kraków, Poland
e-mail: lena.okonska@wp.pl

Małgorzata Daszkiewicz
Freie Universität Berlin
Excellence Cluster 264 TOPOI
Hittorfstr.18, 14195 Berlin, Germany /
ARCHEA
Ogrodowa 8 m95
00-896 Warszawa, Poland
e-mail: m.dasz@wp.pl

Ewa Bobryk
Warsaw University of Technology,
Faculty of Chemistry
ul. Noakowskiego 3,
00-664 Warszawa, Poland
e-mail: bobryk@ch.pw.edu.pl