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TO SMOOTH OR NOT TO SMOOTH? A TRACEOLOGICAL AND EXPERIMENTAL APPROACH TO SURFACE PROCESSING OF BRONZE AND IRON AGE CERAMICS

ABSTRACT

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The biographic approach – that is, tracing artefacts' 'lives' from production, through their use, and finally to their deposition – is commonly applied in the analysis of lithic, flint, and metal artefacts. Objects made of clay, although the most common artifacts at many prehistoric sites, are rarely subject to such studies. In this paper, we focused on the short span of time during the "life" of a ceramic object when its surfaces were smoothed or/and burnished. Both are typical properties of Bronze/early Iron Age pottery found in today's Poland. We studied two factors that influenced the desired final effect: the vessel drying time and the applied tool(s). To accomplish this study, we combined the results of observations of 46 samples from three settlements and two cemeteries in southwestern Poland, as well as the analysis of experimental reference samples. We demonstrated that the drying time was crucial, while the tool kit was composed of rather simple, mostly unprepared, objects such as pebbles or pieces of antler. In the smoothing process, we also observed a connection between surface selection (internal/external) and the purpose to which the vessel was put (settlement/funerary).

Keywords: Bronze Age, early Iron Age, ceramics, experiment, surface treatment, pottery tool kit
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1. INTRODUCTION

That pottery production was one of the basic human activities in the past is reflected in the abundant archaeological evidence dated to the Neolithic onwards. Ceramics have been the subject of studies from the very beginning of professional archaeology, which have analysed them from the angles of typology, technology, contexts, *etc*. However, in the case of clay surfaces, traces and micro traces of their production and use have rarely been studied. This is particularly striking when we compare this paucity of interest with the dynamically developing studies on flint, bone, antler, and recently on metal objects (*e.g*., Legrand and Sidéra 2007; van Gijn 2010; Dolfini and Crellin 2016). However, since recently, this area of study seems to be receiving increasing attention (*e.g*., Lepère 2014; Ionescu *et al.* 2015; Skibo 2015; Calvo *et al.* 2018; Forte *et al.* 2018).

An important contribution to the subject in Polish archaeology is the book by M. Mogielnicka-Urban (1984) in which she discusses working on both wet and dried ceramic surfaces. Basing on the ethnographical data, she argues that the vessels were first smoothed by hand and then polished with a hard tool (Mogielnicka-Urban 1984, 104).

Our main objective was, therefore, to identify the tools used in the finishing techniques commonly employed during the Bronze and Iron Age, *i.e*., smoothing, polishing and burnishing.

Smoothing is a technique for obtaining a finer and more regular surface than the one that results from forming only (Rice 1987, 138) and is applied immediately after forming (Ionescu and Hoeck 2020, 204). Burnishing and polishing techniques result in surface lustre; however, in case of burnishing, linear facets are observed (Rice 1987, 138).

The main questions that arose from the above discussion were:

- can we identify the tools used in surface processing right after the vessels were formed?
- were they *ad hoc* tools (pebbles, ribs of animals), or were the tools worked before use?
- can we observe different patterns in the finishing of vessels used in settlement versus funerary contexts?

2. THE SITES AND MATERIALS

This study is based on a collection of 46 pottery samples from three settlements – namely, Radłowice, Ruszowice, and Wrocław Niemczańska street (10 samples per site) – and two cremation cemeteries: Szprotawa and Miłosławice (6 and 10 samples, respectively). All of them are located in today's SW Poland (Fig. 1) and belong to the periods from the early Bronze Age to the early Iron Age, *i.e*., *ca*. 1800-550 BC (Table 1).

The settlement at Radłowice is located on the loess-based fertile soils in the NE part of the Wrocław Plain. The excavations were carried out in 1968 by S. Pazda (1968), and between 1984 and 1989 by I. Lasak (1993), with a total area of 2,600 m^2 unearthed. The site

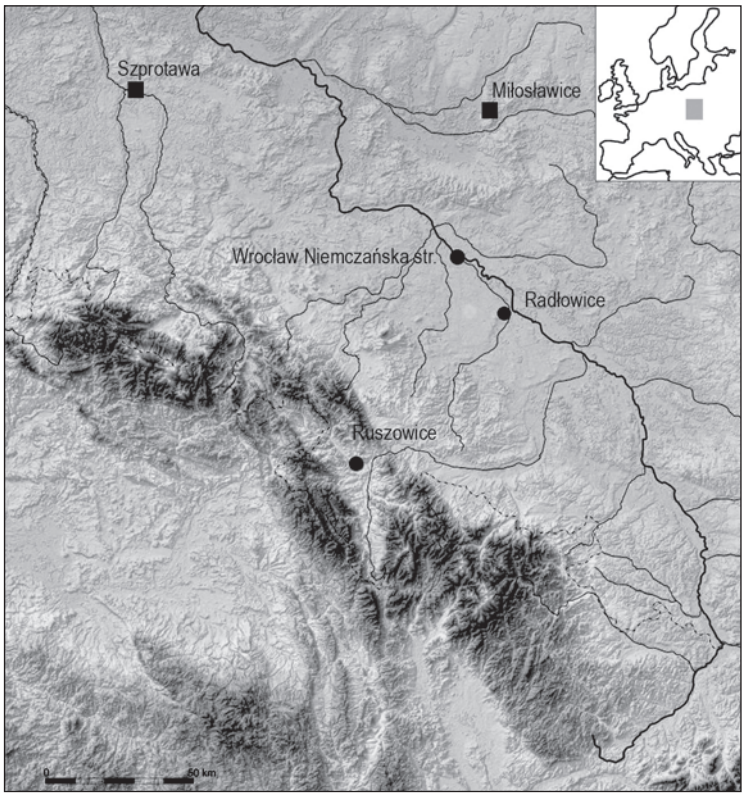

Fig. 1. The studied sites in SW Poland. Squares – cemeteries, circles – settlements (illustrated by A. Gawron-Szymczyk)

was a typical settlement with numerous pits, post-holes, pit houses, and many artefacts made of ceramics, bone, flint, and only few metal objects (Lasak 1993). The pottery is typical for late stages of the early Bronze Age (Lasak 1993, 76-82) and its paste was tempered with fine and medium-grained crushed granite. Ten analysed pieces came from feature no. 1 – a one-metre-deep trench whose interpretation is still ambiguous (Lasak 1990, 117-136; 1991, 87-96).

Another settlement is the site of Ruszowice in the Kłodzko Basin. According to the surface survey, the site covers an area of about 20,000 m^2, of which 940 m^2 were excavated in 2014-2018 (Baron *et al*. 2018). The properties of the ceramics indicate two settlement stages: an early urnfield period (*ca*. 1300-1100 BC) and the early Iron Age (750-550 BC). The analysed samples (6 pieces) come from the occupational layer – two pieces from pit no. 36, located within the outline of a house, one piece from pit no. 45, interpreted as the foundation trench of a building, and one piece from pit no. 51. Due to the high fragmentation of the pottery, we were not able to date the particular samples.

Table 1. Results of macro- and microscopic observation of traces on archaeological samples. Key: sample ID: E – external surface; I – internal surface; site type: se – settlement, cem – cemetery; grave/pit no: layer – occupational layer, st – stray; chronology: EBA – early Bronze Age, MBA – middle Bronze Age, LBA – late Bronze Age, EIA – early Iron Age; surface treatment: sm – smoothed, pol – polished, ro – rough, mt – matte, dmg – damaged; band direction: par – parallel, md – multidirectional

No	Sample ID	Site	Site type	Grave or pit no.	Chronology	Macroscopic features			Microscopic features				Figure
						surface treatment	band	lines inside band	bands		lines inside band		
									width [mm]	direction	occurrence	distance [mm]	
1	Ra-01-E	Radłowice 22	se	1	EBA	sm	+	-	0.5	par	+	0.02	
2	Ra-01-I	Radłowice 22	se	1	EBA	sm	+	-	0.3-0.1	md	-	-	6: c
3	Ra-02-E	Radłowice 22	se	1	EBA	sm	+	+	2	md	+	0.003	
4	Ra-02-I	Radłowice 22	se	1	EBA	sm	+	-	-	-	-	-	
5	Ra-03-E	Radłowice 22	se	1	EBA	pol	-	-	-	-	-	-	
6	Ra-03-I	Radłowice 22	se	1	EBA	pol	-	-	-	-	-	-	
7	Ra-04-E	Radłowice 22	se	1	EBA	sm, film	-	-	0.4	par	-	-	
8	Ra-04-I	Radłowice 22	se	1	EBA	dmg	-	-	-	-	-	-	
9	Ra-05-E	Radłowice 22	se	1	EBA	pol	+	-	0.6	par	-	-	
10	Ra-05-I	Radłowice 22	se	1	EBA	pol	+	-	0.6	md	-	-	
11	Ra-06-E	Radłowice 22	se	1	EBA	sm	+	+	1	md	+	0.03-0.06	6: b
12	Ra-06-I	Radłowice 22	se	1	EBA	sm	+	-	0.5	par	+	0.03	
13	Ra-07-E	Radłowice 22	se	1	EBA	film	-	-	-	-	-	-	
14	Ra-07-I	Radłowice 22	se	1	EBA	film	-	-	-	-	-	-	
15	Ra-08-E	Radłowice 22	se	1	EBA	pol	-	-	-	-	-	-	6: a
16	Ra-08-I	Radłowice 22	se	1	EBA	dmg	-	-	-	-	-	-	
17	Ra-09-E	Radłowice 22	se	1	EBA	pol	-	-	-	-	-	-	

18	Ra-09-I	Radłowice 22	se	1	EBA	dmg	-	-	-	-	-	-	
19	Ra-10-E	Radłowice 22	se	1	EBA	sm	-	-	0.7	md	-	-	
20	Ra-10-I	Radłowice 22	se	1	EBA	film	-	-	-	-	-	-	
21	S-11-E	Szprotawa Niepodległości av.	cem	1	MBA	film	-	-	0.3	par	-	-	
22	S-11-I	Szprotawa Niepodległości av.	cem	1	MBA	dmg	-	-	-	-	-	-	
23	S-12-E	Szprotawa Niepodległości av.	cem	5	MBA	ro	-	-	-	-	-	-	
24	S-12-I	Szprotawa Niepodległości av.	cem	5	MBA	sm	+	+	1.1	par	+	0.03-0.07	7: a
25	S-13-E	Szprotawa Niepodległości av.	cem	st	MBA	film	-	-	0.7	par	+	0.7	7: c
26	S-13-I	Szprotawa Niepodległości av.	cem	st	MBA	film	-	-	-	-	-	-	
27	S-14-E	Szprotawa Niepodległości av.	cem	1	MBA	pol, film	-	-	-	-	-	-	
28	S-14-I	Szprotawa Niepodległości av.	cem	1	MBA	pol, film	-	-	-	-	-	-	
29	S-15-E	Szprotawa Niepodległości av.	cem	1	MBA	pol	+	+	0.9	par	-	-	
30	S-15-I	Szprotawa Niepodległości av.	cem	1	MBA	pol	+	+	0.9	md	+	0.1-0.2	7: b
31	S-16-E	Szprotawa Niepodległości av.	cem	1	MBA	sm, film	+	-	0.9	par	-	-	
32	S-16-I	Szprotawa Niepodległości av.	cem	1	MBA	sm, dmg	+	-	0.4-0.6	par	-	-	
33	Ru-17-E	Ruszowice 5	se	layer	MBA-EIA	sm, mt	-	-	-	-	-	-	
34	Ru-17-I	Ruszowice 5	se	layer	MBA-EIA	pol	+	-	1.75	par	-	-	
35	Ru-18-E	Ruszowice 5	se	36	MBA-EIA	sm, mt	-	-	-	-	-	-	
36	Ru-18-I	Ruszowice 5	se	36	MBA-EIA	sm	+	-	1.75	par	-	-	

Table 1.

No	Sample ID	Site	Site type	Grave or pit no.	Chronology	Macroscopic features			Microscopic features				Figure
						surface treatment	band	lines inside band	bands		lines inside band		
									width [mm]	direction	occurrence	distance [mm]	
37	Ru-19-E	Ruszowice 5	se	36	MBA-EIA	sm, mt	-	-	-	-	-	-	
38	Ru-19-I	Ruszowice 5	se	36	MBA-EIA	film	+	-	0.8	par	-	-	
39	Ru-20-E	Ruszowice 5	se	45	MBA-EIA	sm, mt	-	-	-	-	-	-	
40	Ru-20-I	Ruszowice 5	se	45	MBA-EIA	film	-	-	-	-	-	-	
41	Ru-21-E	Ruszowice 5	se	layer	MBA-EIA	sm, mt	-	-	-	-	-	-	
42	Ru-21-I	Ruszowice 5	se	layer	MBA-EIA	film	-	-	-	-	-	-	
43	Ru-22-E	Ruszowice 5	se	51	MBA-EIA	sm, mt	-	-	-	-	-	-	
44	Ru-22-I	Ruszowice 5	se	51	MBA-EIA	sm	+	-	1.7	md	-	-	6: f
45	Ru-23-E	Ruszowice 5	se	layer	MBA-EIA	sm, mt	-	-	-	-	-	-	
46	Ru-23-I	Ruszowice 5	se	layer	MBA-EIA	sm, mt	-	-	-	-	-	-	
47	Ru-24-E	Ruszowice 5	se	layer	MBA-EIA	mt	-	-	-	-	-	-	6: e
48	Ru-24-I	Ruszowice 5	se	layer	MBA-EIA	film	-	-	0.9	par	+	0.1	6: d
49	Ru-25-E	Ruszowice 5	se	layer	MBA-EIA	sm, film	+	-	0.6	par	-	-	
50	Ru-25-I	Ruszowice 5	se	layer	MBA-EIA	sm	+	-	0.6	par	+	0.03-0.06	
51	Ru-26-E	Ruszowice 5	se	layer	MBA-EIA	sm	+	+	1.9	par	-	-	
52	Ru-26-I	Ruszowice 5	se	layer	MBA-EIA	sm, mt	-	-	-	-	-	-	
53	N-27-E	Wrocław, Niemczańska st.	se	111	LBA	sm	+	-	1.3	par	-	-	6: g
54	N-27-I	Wrocław, Niemczańska st.	se	111	LBA	film	+	-	1.3	par	-	-	6: h
55	N-28-E	Wrocław, Niemczańska st.	se	150	LBA	dmg	-	-	-	-	-	-	

56	N-28-I	Wrocław, Niemczańska st.	se	150	LBA	film	+	-	1.3	par	-	-	
57	N-29-E	Wrocław, Niemczańska st.	se	157	LBA	film	-	-	-	-	-	-	
58	N-29-I	Wrocław, Niemczańska st.	se	157	LBA	film	-	-	-	-	-	-	
59	N-30-E	Wrocław, Niemczańska st.	se	180	LBA	pol	+	-	2.3	par	+	0.5	
60	N-30-I	Wrocław, Niemczańska st.	se	180	LBA	film	-	-	-	-	-	-	
61	N-31-E	Wrocław, Niemczańska st.	se	177	LBA	pol	+	-	1	md	+	0.1-0.03	
62	N-31-I	Wrocław, Niemczańska st.	se	177	LBA	pol	+	-	1	par	-	-	6: i
63	N-32-E	Wrocław, Niemczańska st.	se	104	LBA	dmg	-	-	-	-	-	-	
64	N-32-I	Wrocław, Niemczańska st.	se	104	LBA	pol	+	-	1.1	md	-	-	
65	N-33-E	Wrocław, Niemczańska st.	se	197	LBA	pol, dmg	+	+	1.3	par	-	-	
66	N-33-I	Wrocław, Niemczańska st.	se	197	LBA	film	-	-	-	-	-	-	
67	N-34-E	Wrocław, Niemczańska st.	se	103	LBA	sm, mt	-	-	-	-	-	-	
68	N-34-I	Wrocław, Niemczańska st.	se	103	LBA	sm, mt	-	-	-	-	-	-	
69	N-35-E	Wrocław, Niemczańska st.	se	111	LBA	film	-	-	-	-	-	-	
70	N-35-I	Wrocław, Niemczańska st.	se	111	LBA	film	-	-	-	-	-	-	
71	N-36-E	Wrocław, Niemczańska st.	se	111	LBA	film	-	-	-	-	-	-	
72	N-36-I	Wrocław, Niemczańska st.	se	111	LBA	sm	-	-	0.03	md	-	-	
73	M-37-E	Miłosławice 6	cem	374	EIA	sm	+	-	0.4	par	-	-	

Table 1.

No	Sample ID	Site	Site type	Grave or pit no.	Chronology	Macroscopic features			Microscopic features				Figure
						surface treatment	band	lines inside band	bands		lines inside band		
									width [mm]	direction	occurrence	distance [mm]	
74	M-37-I	Miłosławice 6	cem	374	EIA	film	-	-	-	-	-	-	
75	M-38-E	Miłosławice 6	cem	52	EIA	film	-	-	-	-	-	-	
76	M-38-I	Miłosławice 6	cem	52	EIA	sm	-	-	-	-	-	-	
77	M-39-E	Miłosławice 6	cem	51	EIA	film	-	-	-	-	-	-	7: f
78	M-39-I	Miłosławice 6	cem	51	EIA	sm	-	-	-	-	-	-	7: e
79	M-40-E	Miłosławice 6	cem	434	EIA	sm	-	-	-	-	-	-	
80	M-40-I	Miłosławice 6	cem	434	EIA	film	-	-	-	-	-	-	
81	M-41-E	Miłosławice 6	cem	489	EIA	film	+	-	1	par	+	0.03-0.06	7: d
82	M-41-I	Miłosławice 6	cem	489	EIA	dmg	-	-	-	-	-	-	
83	M-42-E	Miłosławice 6	cem	61	LBA	film	-	-	-	-	-	-	
84	M-42-I	Miłosławice 6	cem	61	LBA	sm	-	-	-	-	-	-	
85	M-43-E	Miłosławice 6	cem	196a	EIA	ro	-	-	-	-	-	-	
86	M-43-I	Miłosławice 6	cem	196a	EIA	film	-	-	-	-	-	-	
87	M-44-E	Miłosławice 6	cem	37	LBA	film	+	-	-	-	-	-	
88	M-44-I	Miłosławice 6	cem	37	LBA	film	-	-	-	-	-	-	
89	M-45-E	Miłosławice 6	cem	65	LBA	pol	+	-	2	-	-	-	
90	M-45-I	Miłosławice 6	cem	65	LBA	film	-	-	-	-	-	-	
91	M-46-E	Miłosławice 6	cem	199	LBA	film	+	-	-	-	-	-	
92	M-46-I	Miłosławice 6	cem	199	LBA	sm	+	-	0.6	md	+	0.03-0.06	

In Wrocław Niemczańska street, a site attributed to late stages of the Bronze Age (*ca*. 1100-750 BC) was excavated before construction works. From 205 pits of various functions, numerous pottery sherds, daub lumps, and slags were excavated (Panek 2012; Kądziołka 2016). Three pieces came from pit 111, and one piece each from pits 103, 104, 150, 157, 177, 180, and 197.

The urnfield at Szprotawa was located in the town centre at Niepodległości avenue and was excavated before a road was constructed over it (Panek 2012). The site consisted of five partly destroyed graves furnished with a typical urnfield set of grave goods, *i.e*., pottery and a few metal objects. We sampled four vessels from grave no. 1, vessel no. 2 from grave 5 (one piece), and one stray piece – six samples in total. The bones from grave 5 were dated to 1372-1128 BC (with 95.4% probability interval) with a carbon-14 test, which corresponds well with the artefact-based chronological period – Montelius III (1300-1100 BC).

The last site is a large urnfield at Miłosławice, excavated in the 1960s and then in 1995-2004. The total number of graves excavated in the 1995-2004 campaigns is 501. In general, the chronology covers late stages of the Bronze Age up to the early Iron Age (*i.e*., 1100-550 BC; Lasak 1996). The samples come from late Bronze Age graves dated roughly to 900-750 BC (one sample each from graves 37, 61, 65 and 199), and early Iron Age graves, *i.e*., *ca*. 750-550 BC (one sample each from graves 51, 52, 196a, 374, 434 and 489).

3. METHODS

The sample selection was based on the variability of traces observed with the naked eye. We selected sherds – both those with clearly visible traces of tools, and other heavily polished, smooth, lustrous pieces – to test whether the traces can be observed in further research. Then, the macroscopic documentation was done with the use of a Canon camera (EOS550D, lens EFS 18-55 mm). The micro traces were analysed at the Laboratory of Archaeometry and Artefact Conservation at the Institute of Archaeology, Wrocław University with the use of a stereoscopic microscope Olympus SZX9 (magnification 6,4-10×). In the observation and documentation process, the Lucia Measurement software and Nikon DS-5-U1 camera were used.

To verify and interpret the observations, an experiment was designed to produce reference samples. We applied the experimental protocol introduced by P. Richter (1991). The reference samples were 15 bowls of about 5 cm in diameter and about 3 cm high. The paste was red clay tempered with fine (<2 mm) sand in a 4:1 ratio. Each bowl weighed 50 g and had nine-milimetre-thick walls. They were made from a single lump of clay and dried in a dark, windless room at a temperature of about 20°C. They were then divided into three groups (I-III) according to their drying time, which was 2, 24, and 72 hours, respectively. The tools used to smooth the unworked surfaces were a pig rib, a piece of fired pottery made of plastic clay tempered with granite, a quartzite pebble, a smooth piece of pinewood,

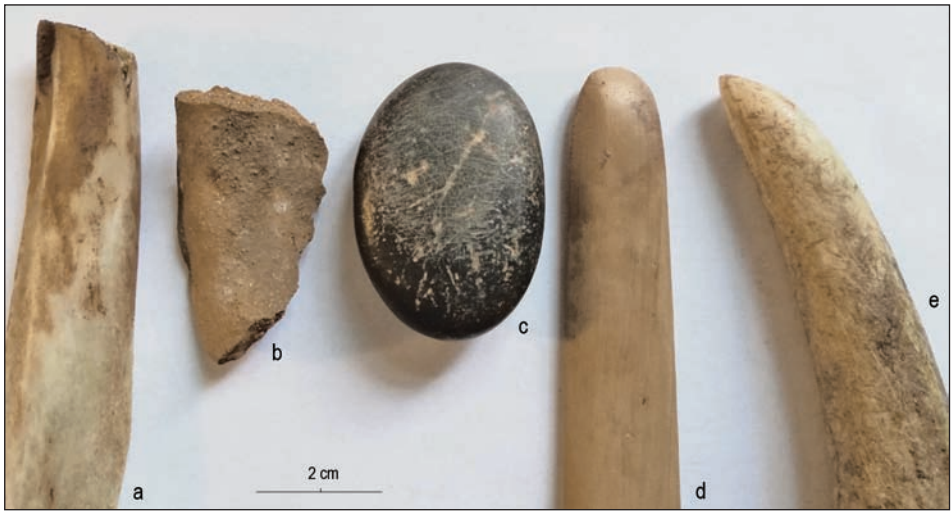

Fig. 2. Smoothing tools used in the experiment: a – rib; b – sherd of pottery; c – pebble; d – wooden stick; e – antler (photo by A. Gawron-Szymczyk)

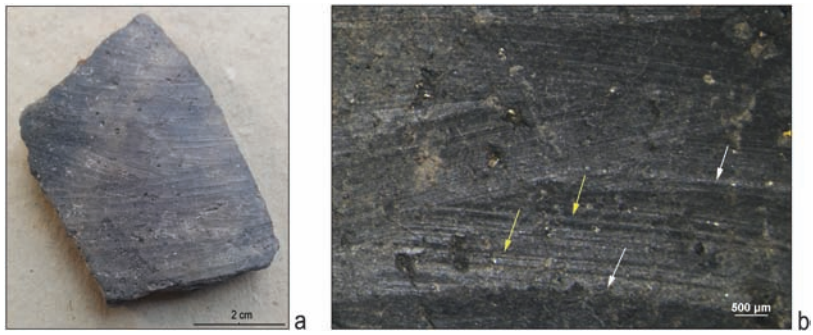

Fig. 3. Macroscopic (a) and microscopic (b) images of a worked surface of early Bronze Age pottery from Radłowice (sample Ra-06-E). White arrows indicate band edges (protrusions), yellow arrows denote lines inside band (photo by A. Gawron-Szymczyk)

and a smooth piece of red deer antler (Fig. 2). During the smoothing process, a uniform pressure was applied on the surfaces. Each bowl was smoothed for 5 minutes with regular, circular movements.

The firing was then done in an electric kiln, in an oxidizing atmosphere with hourly temperature increases of 50°C to reach a maximum of 600°C. The firing lasted 14 hours and 30 minutes, including 30 minutes at the maximum temperature. After the firing, the traces were observed under a microscope. The observations focused on all the traces created while smoothing the surfaces. Most of the traces were in the form of bands of various

shapes and running in various directions. Small portions of clay were seen accumulated along the edges of the bands, forming protrusions, while inside the bands, parallel lines made by the tools were observed. They corresponded well with the traces observed on prehistoric pieces (Fig. 3).

4. RESULTS

Experimental Pottery

The experiment proved that the main factor influencing the surface smoothness was the drying time of the vessel before the smoothing started (Table 2). The humidity of the

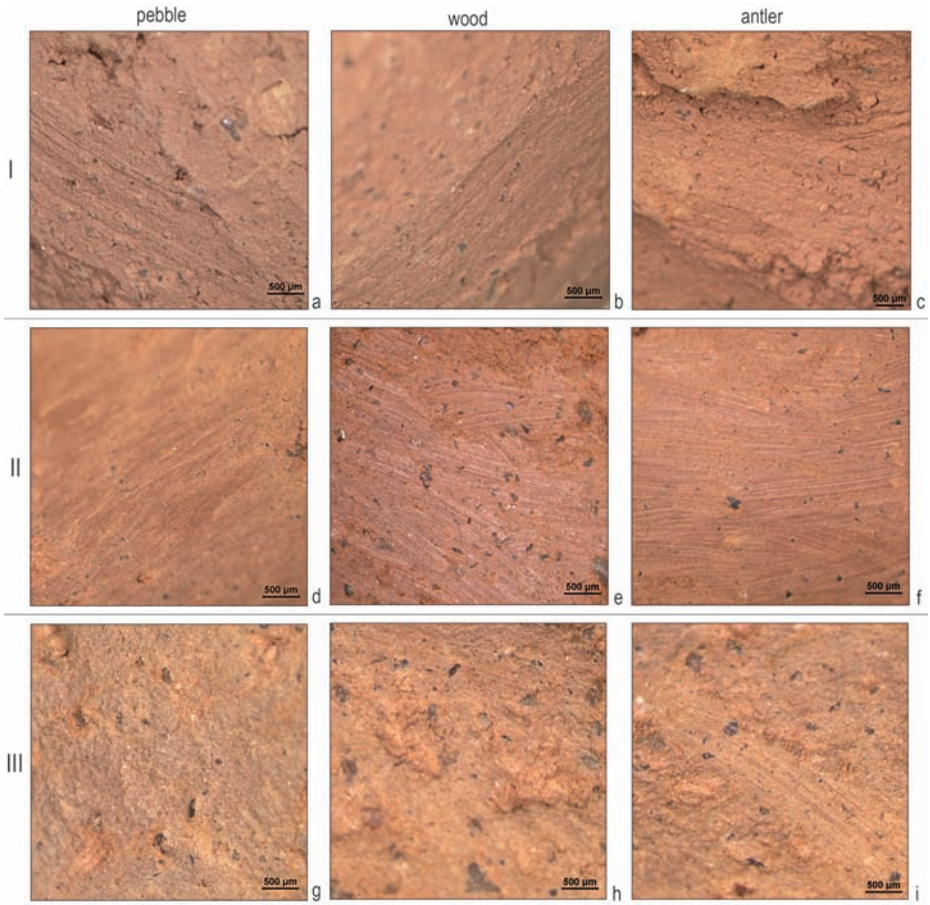

Fig. 4. Traces of tools on the experimental pottery. Labels I-III denote groups according to the drying time (photo by A. Gawron-Szymczyk)

Table 2. Results of microscopic observation of traces obtained on reference pottery. Key: group I-III: drying time (2, 24, 72 hours respectively); effect on the surface (macroscopic): ro – rough, sm – smooth, pol – polished; band direction: fr – frayed, par – parallel, w – wavy

No	Group	Tool	Effect on the surface (macroscopic)	Microscopic observations				Comments	Figure
				band		lines inside band			
				occurence	direction	occurence	width [mm]		
1	I	rib	ro	+	fr	+	0.08-0.1		
2		shard	ro	-	-	-	-		
3		pebble	ro	+	par, fr	+	0.05		4: a
4		wood	sm	+	par, fr	+	0.03-0.1		4: b
5		antler	ro	+	par, w	+	0.4		4: c
6	II	rib	sm	+	par	+	0.2	mildirectional lines in the bands	
7		shard	no traces	-	-	-	-	traces on the worked surface occured only in contact spot of the mineral temper of the tool	
8		pebble	sm	+	par	+	0.04		4: d
9		wood	pol	+	par	+	0.06-0.09		4: e
10		antler	pol	+	par	+	0.01		4: f
11	II	rib	sm	+	fr	+	0.2		
12		shard	ro	+	par, fr	+	0.03		
13		pebble	film	-	-	-	-		4: g
14		wood	no traces	-	-	+	0.1	no band edges observed	4: h
15		antler	no traces	-	-	+	0.1		4: i

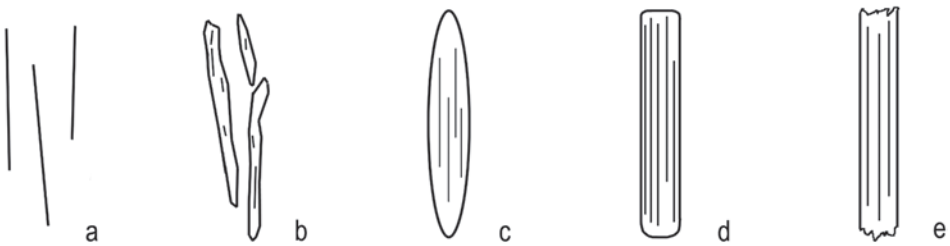

Fig. 5. Schematic traces of tools observed on bowls from group II:
a – rib; b – sherd of pottery; c – pebble; d – wooden stick; e – antler
(illustrated by A. Gawron-Szymczyk)

paste, the temperature, and possible air movements during the drying process were, therefore, crucial for the effectiveness of surface working, but relatively difficult to control in the course of the experiment.

The bowls that were dried for 2 hours (group I) were too wet to be smoothed – all the tools went too deep into the surfaces and left rough traces (Fig. 4: a-c).

Smooth surfaces with clearly visible, shining bands were noticed only in group II, which had been left to dry for 24 h. This group seems to have optimally hard walls for the use of the smoothing tools, which neither damaged the surface with deep bands nor caused abrasion (Fig. 4: d-f).

Also, the bowls from group III, which were left to dry for 72 hours, were too dry, and working their surfaces resulted in micro chippings or even abrasion on the vessels' walls (Fig. 4: g-i). The tools left only poorly visible traces, mostly concentrated in zones in which the paste was probably more moist.

The characteristics of traces on the bowls left to dry for 24 hours are presented in the following paragraphs.

The pig's rib left deep, poorly visible, matte grooves (Fig. 5: a). The piece of pottery seemed to be the least effective due to temper grains, which left irregular bands and grooves on the smoothed surface (Fig. 5: b). The traces of smoothing with pebbles were clearly visible as lenticular, matte bands of similar sizes and with straight edges. The lines inside the bands were shallow, dense, and parallel (Fig. 4: a, d, g; 5: c). The bands made by the piece of wood were more rectangular, deeper, and lustrous inside. The lines inside the bands were parallel, but denser and deeper compared to those made by pebbles (Fig. 4: b, e, h; 5: d). The piece of antler left the bands with irregular, notched ends, and the lines within the bands were deep, but not dense (Fig. 4: c, f, i; 5: e).

Among the tools used in the experiment, the pebble and the piece of pine wood seemed to be the most effective. Even in group I, their impact on the surface was lower compared to other tools (Fig. 4: a, b).

Prehistoric Pottery

The traces observed under the microscope on the archaeological samples were most similar to those observed on the experimental bowls from group II, *i.e.*, the group that was left to dry for 24 hours. Based on the results of the experiments, we identified such tools as pebbles, wood, antler, and rib.

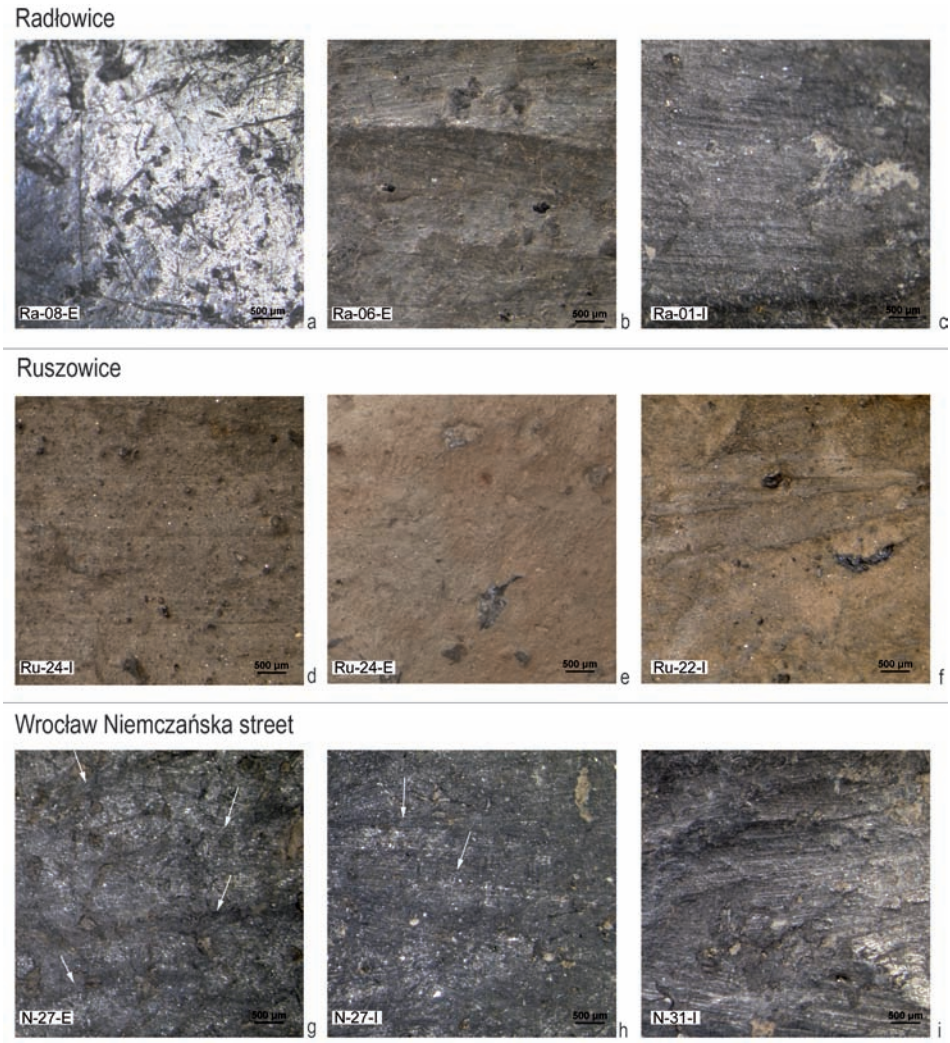

Fig. 6. Traces of tools on the ceramics from the settlements: a – polishing (no traces observed), b, d, e, g, h – pebble, c, i – wood, f – antler. White arrows denote traces of similar pebble use. The sample IDs are given in the lower left corner of each image (photo by A. Gawron-Szymczyk)

Table 3. Traces of tools on the archaeological samples

Tool	Settlement			Cemetery		
	Radłowice	Ruszowice	Wrocław Niemczańska	Szprotawa	Miłosławice	
pebble	2	7	5	5	8	= 27
wood	3	-	2	-	-	= 5
antler	1	2	-	-	-	= 3
rib	-	-	-	1	-	= 1
shard	-	-	-		-	= 0
Total	**6**	**9**	**7**	**6**	**8**	= 36

Of the 46 sherds in the sample, traces of tools were observed on 36 pieces (Table 3). On ten of the sample sherds, the tools remained unidentified, mostly due to intense polishing.

The most common traces were made by pebbles (27 pieces), wooden tools (5 pieces), antler (3 pieces), and a rib tool (1 piece). None bore traces of working with a piece of pottery. Therefore, the most common tools were simple, unprepared objects – smooth quartzite pebbles and pieces of antler in this case. Wood could easily have been used as well.

Interestingly, each piece (internal and external surface) was worked with one tool only, *i.e.*, the potters were able to smooth all the curved surfaces with one small object.

At the early Bronze Age settlement at Radłowice, 4 fragments were smoothed with unidentified tools, and the surfaces were heavily polished (Fig. 6: a). It seems that soft smoothers such as fur, leather, or textile might have been used. However, confirmation of that will require further experiments. This is also the only site where traces of pebbles (observed on two pieces – Fig. 6: b) did not prevail over the use of a wooden tool (3 pieces – Fig. 6: c). On one piece, traces of the use of an antler were observed.

Very interesting traces were observed on the collection from the settlement at Ruszowice. The pottery was smoothed with pebbles (7 pieces), but it seems that this work was done on dryer surfaces than in other cases. The smoothing was observed mostly on the inner surfaces of six pieces (Fig. 6: d), while the external surface of one was matte (Fig. 6: e), probably worked by hand only. Therefore, we may conclude that the smoothing was done to improve the vessel's watertightness; however, its original form, *i.e.*, its probable function, cannot be reconstructed due to the high fragmentation. Antler was used on two other pieces – again on their inner surfaces only (Fig. 6: f). The tool used for one fragment could not be recognised.

At the settlement from Wrocław Niemczańska street, the pottery was worked with pebbles five pieces), and similar bands were observed on the outer and inner surfaces (Fig. 6: g, h). Two pieces were worked with a wooden tool (Fig. 6: i). Another three pieces were covered with a thin film, but this technique remains unrecognized.

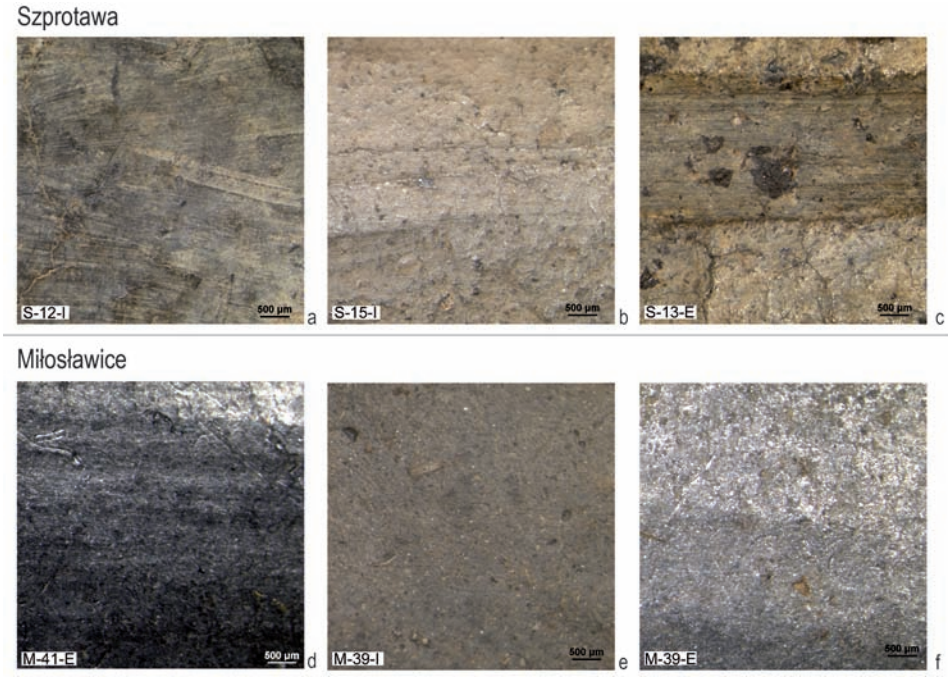

Fig. 7. Traces of tools on the ceramics from the cemeteries: a – rib tool, b-d, f – pebble, e – no traces. The sample IDs are given in the lower left corner of each image (photo by A. Gawron-Szymczyk)

The pottery from the cemetery at Szprotawa was worked with a rib (Fig. 7: a) and with pebbles (5 pieces – Fig. 7: b). In the case of a decorated sherd, the pattern of parallel bands was likely made with a thin pebble (Fig. 7: c).

Among the samples from the cemetery at Miłosławice, eight fragments were smoothed with pebbles, while unidentified tools were used on two others. In the case of this site, smoothing was done very carefully, and so the traces (in the form of parallel lines) were rather minimal (Fig. 7: d). Interestingly, seven pieces did not show any traces of smoothing inside the vessel, though these were evident on its outer surface (Fig. 7: e, f). It seems that in this case, improving the vessel's impermeability was not the objective. The vessel's inner surface was porous, and thus its absorptivity must have been significantly higher.

5. DISCUSSION

The modes of surface treatment of ceramic artifacts from Polish archaeological sites, and the tools used for the treatment, have not previously been subjects of research. Experimental observations in various scales in the current study have led to the identification

of the tools used in treatments and the characteristic traces they leave on the surfaces of partly dried vessels.

There are some opinions in the literature about ceramic processing on materials of varying stages of dryness, and about surface burnishing performed on dry vessels (Mogielnicka-Urban 1984, 104; Orton *et al.* 1993, 126). Our experiments showed that better results can be achieved on slightly moist surfaces, on which micro chippings rarely occur, and a smooth texture and lustrous burnish are achieved more quickly.

Similar research, including micro observations and experiments, have been done on Neolithic pottery (4000-3800 cal. BC) from the Gava cave in SE Spain (Calvo *et al.* 2018, 251-256). Replicas of the pottery were made from the local clay, and the final surface treatment was done with small rocks on vessels at various levels of dryness. The results were similar to ours, but were not used to interpret traces of tools on the prehistoric pottery from this site.

In our research, we managed to prove that the most common tools used in the smoothing process were pebbles of various sizes. An interesting question that remains is how a perfectly smooth and shiny surface (as in the examples from Radłowice) was obtained, as the experiment proved that smoothing with the use of various tools was not enough for such a result. Ethnographic data from Central America showed a two-stage process of surface treatment – first, the use of pebbles and hands, followed by wet textiles (Shepard 1956, 65-69). In archaeological literature, it is also noted that pottery might have been polished with pieces of leather (Gądzikiewicz 1954), but M. Mogielnicka-Urban argues that the use of leather leaves the surface smooth, but matte (1984, 104). Therefore, further use of hard tools (pebbles of various sizes) cannot be ruled out. Interestingly, the possible two-stage smoothing process seems to be typical only for early Bronze Age material, and is observed on both settlement pieces and funerary pieces.

There is a widely held opinion that many objects used in pottery production might have had other functions previously, *i.e.*, they were not originally designed as specialist tools for potters. A good example is that of small ceramic discs (usual diameters 5-10 cm) with smooth rounded edges (*e.g.*, at Wrocław Niemczańska Street – Fig. 8: a, b). They are considered to be potsherds transformed for secondary use as smoothers (Venclová *et al.* 2019). Our experiment, however, demonstrated that potsherds are not suitable for smoothing, as they contain temper which leaves deep linear traces on the worked surfaces (Fig. 8: c, d). Therefore, we argue the ceramic discs were not used as smoothers but might have had other functions like toys, pieces in games, *etc.* (Żychlińska 2015, with further references therein).

Why were the surfaces smoothed? To improve quality or aesthetics? In our collection, the settlement vessels were more often smoothed and burnished inside, while the outer surfaces were rather matte. That may, therefore, suggest contact with liquids or semi-liquid content, requiring higher ware watertightness, which was achieved by intense smoothing. On the other hand, the grave vessels were not smoothed inside, and therefore,

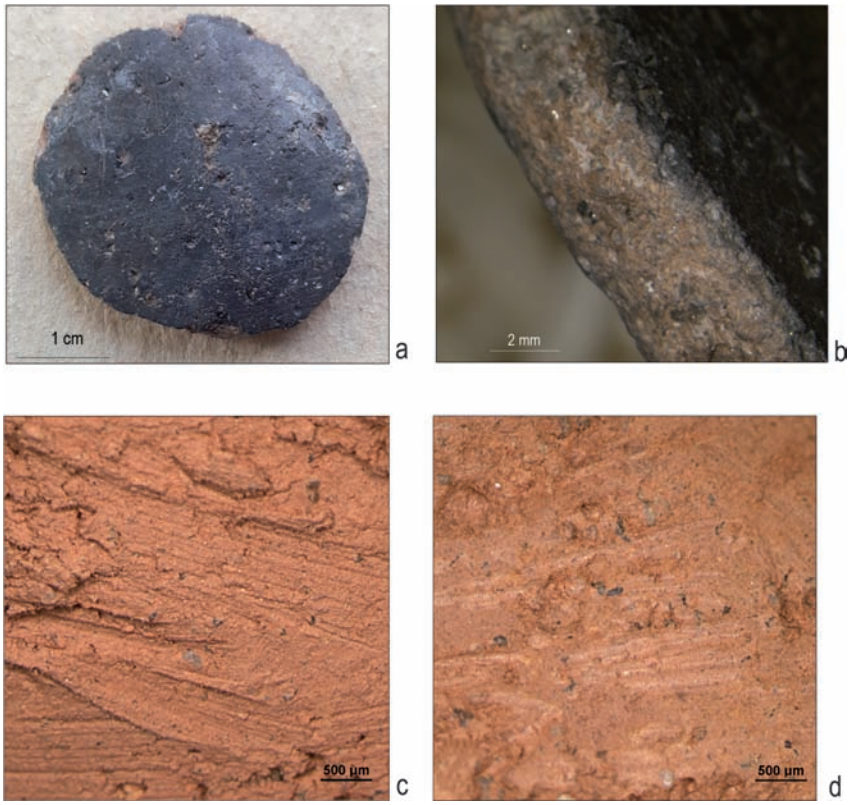

Fig. 8. Ceramic smoothers? a – ceramic disc from the settlement at Wrocław Niemczańska street and b – its rounded edge under the microscope, c – traces of use of ceramic smoother on experimental vessels from group I, d – traces of use of ceramic smoother on experimental vessels from group II (photo by A. Gawron-Szymczyk)

their walls remained relatively porous and absorptive. That may exclude them from many everyday uses, such as for storing, processing and serving food. Their carefully worked outer surfaces suggest rather a desire for obtaining a smooth and shiny or lustrous effect. Our results cannot be compared with data from other sites, as the smoothers have never been studied and published.

6. CONCLUSIONS

Our research enabled the identification of tools used in processing surfaces of ceramic vessels of various types (settlements, cemeteries) from archaeological and chronological contexts (from the early Bronze Age to the early Iron Age). Based on observations of archaeological samples and experimental reference materials, the main conclusions are:

1. The efficiency of surface treatment depended mostly on the degree of ceramic moisture, and the traces observed on archaeological samples corresponded the most with experimental smoothing performed at about 24 hours after the vessels were made.

2. The most common tools used in this process were simple, small pebbles. Evidence of the use of pottery sherds was not found.

3. Some of the vessels' surfaces, mostly in the early Bronze Age, were heavily polished, which suggests two stages in surface processing, *i.e.*, smoothing with unidentified tools and then further smoothing using some soft material.

4. The settlement vessels were smoothed mostly on the inside, which may confirm that the smoothing was applied to improve the impermeability of the container.

5. Unlike the settlement pottery, the funerary vessels were usually smoothed on the outside only, which did not influence their porosity and absorptivity. That may suggest they were not made for everyday use.

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