ARCHAEOMETRIC EXAMINATION OF EARLY AND MIDDLE BRONZE AGE CERAMICS FROM SZÁZHALOMBATTA-FÖLDVÁR, HUNGARY

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Kivonat

A dolgozat a százhalombattai kora és középső bronzkori tell-település kerámiáinak a technológiai jellemzőit vizsgálja polarizációs és katódlumineszcens petrográfia, röntgen-pordiffrakciós (XRD) és röntgenfluoreszcens (XRF) vizsgálatok segítségével. A középső bronzkor végén, a Koszider időszakban, a kerámiák készítés-technikája kidolgozottabbá vált, kifinomult díszítési eljárások, jól kidolgozott felületkezelési eljárások és jól kontrollált kiégetési körülmények figyelhetők meg. Ebben a dolgozatban összesen nyolc, a finom és a durva kerámiához sorolható edénytöredéket vizsgáltunk. Annak érdekében, hogy bővebb képet kapjunk arról, hogy a fazekasok hogyan módosíthatták a nyersanyagaikat, a tell környékéről származó agyagmintákat is vizsgáltunk az említett módszerekkel. Az eredmények arra engednek következtetni, hogy a fazekasok helyi nyersanyagokat használtak a vizsgált kerámiák készítéséhez, s a legjobban kidolgozott és díszített kerámiák (rákospalotai típus) is helyben készültek. Annak ellenére, hogy a különböző kerámiák készítéséhez felhasznált nyersanyagok összetétele hasonló, megfigyelhető, hogy a fazekasok különbözőképpen módosították a nyersanyagokat és eltérő soványítási eljárásokat választottak. Ez a változatosság egy bizonyos edénytípuson belül is megfigyelhető. A különböző választások a nyersanyagok és soványítóanyagok tekintetében a településen belüli helyi hagyományok kialakulásához vezetett.

Abstract

This paper examines the technological aspects of Early and Middle Bronze Age ceramics from a tell settlement at Százhalombatta (Hungary) by using polarising and cathodoluminescence microscopy, X-ray diffraction (XRD) and X-ray fluorescence spectroscopy (XRF) analyses. Towards the end of the Middle Bronze Age, during the Koszider period, ceramic production became more elaborate; and highly distinctive vessels appeared in terms of their decoration, surface treatment and firing conditions. For this analysis eight sherds belonging to fine and coarse wares were selected. In order to assess how potters may have altered their raw materials potential clay samples around the tell settlement were also examined by the same techniques. Results suggest that potters used locally available clays and even the most distinct vessels in terms of decoration (Rákospalota type wares) seem to be locally made. In spite of the similarities in clay compositions, however, there is a clear distinction between how potters manipulated their clay and temper even within a similar vessel type. This practice resulted in the existence of intrasite technological traditions.

KULCSSZAVAK: BRONZKOR, MAGYARORSZÁG, KERÁMIA TECHNOLÓGIA, KERÁMIA PETROGRÁFIA, RÖNTGEN-PORDIFFRAKCIÓ, RÖNTGENFLUORESZCENCIA, KATÓDLUMINESZCENCIA

KEYWORDS: BRONZE AGE, HUNGARY, CERAMIC TECHNOLOGY, CERAMIC PETROGRAPHY, X-RAY DIFFRACTION, X-RAY FLUORESCENCE ANALYSIS, CATHODOLUMINESCENCE

Figure 1.

a) Map of Hungary with the location of Százhalombatta,

b) Photo of the tell from south,

c) The tell represented by the First Military Survey of Hungary (1763-1785).

Introduction

This paper examines the composition of Early and Middle Bronze Age sherds from a tell settlement at Százhalombatta, Hungary. Ceramic and local clay samples were subjected to a series of analyses by different analytical techniques in order to characterise their composition.

It must be noted that in this paper the word 'clay' is used as a general term to designate potential raw materials with any clay content that may have been used for potting regardless of the type and amount of clay minerals in them.

It is aimed to assess the differences of ceramic samples in terms of technological practices and provenance. The scientific methods applied in this study allow us to assess the use of different clays and tempers for potting and estimate firing temperatures. The results are evaluated through comparison of different vessel types and mineralogical data and used to assess different aspects of Bronze Age ceramic production and distribution. The sherds chosen for this analysis belong to different vessels and typological groups. They also show differences in terms of macroscopic and microscopic characteristics. It is aimed to assess whether different vessel types (e.g. fine wares and coarse wares) or different technological practices (e.g. untreated or highly burnished and decorated wares) can be associated with a particular raw material and whether the examined sherds, in particular the fine wares were locally made.

Archaeological background

The tell settlement of Százhalombatta is situated 30 km south of Budapest on the eastern margin of the Mezőföld (**Fig. 1a**). The tell settlement occupies a high natural elevation on the right bank of the Danube (**Fig. 1b-c**).

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Topographical survey has identified 13 Bronze Age sites around Százhalombatta in the valley of the Benta river. Most of the finds were dated to the Early Bronze Age Nagyrév and Middle Bronze Age Vatya cultural groups (Poroszlai 2000, 14). During the Vatya period, the tell of Százhalombatta-Földvár was surrounded by a ditch and rampart system (Kovács 1969, 161).

The first excavation in 1963 aimed to investigate the structure of the settlement, explore the relationship between the Nagyrév and Vatya cultural groups and refine the existing relative chronology of the Early and Middle Bronze Age (Kovács 1969). During the excavation five major construction periods were distinguished. Unfortunately, houses were not found among the excavated features, although the excavation revealed many pits and hearths characteristic of the Vatya culture. Analysis of the excavated assemblages showed that the tell was inhabited from the second part of the Early Bronze Age Szigetszentmiklós phase of the Nagyrév culture until the Iron Age. It must be noted, however, that after the Middle Bronze Age the settlement was abandoned and re-occupied during the Late Bronze Age Urnfield society followed by the Celts (Kovács 1969, 161). The excavation in 1969 revealed that the majority of the ceramic finds could be dated to the Vatya society and its latest Koszider phase.

In order to explore possible continuity and changes in settlement patterns an excavation begun in 1989. The excavation identified six construction phases with house remains, hearths and many pits characteristic of the Vatya culture. The significance of this excavation is that it extended to a bigger area than the 1969 excavation, which allowed a better understanding of changes and continuity in settlement patterns. Furthermore, a scientific team investigated the archaeobotanical remains, bone and stone tools (Poroszlai 2000, 16). The last construction episode of the Vatya (Level 2), which comprises the Koszider period, presented the most elaborately made ceramics. The most characteristic finds are highly sophisticated black burnished cups, bowls and jars with elaborate decoration. The richest pit (Pit 2) in terms of the number of finds representing the Koszider period provided many jars, cups, jugs and bowls with great labour input in terms of surface embellishments (Poroszlai 2000; Kreiter 2005). Levels 3 and 4 also represented the Vatya phase while Level 5 and 6 revealed parts of a Nagyrév occupation (Poroszlai 2000, 32). The excavation revealed no changes or differences between the Nagyrév and Vatya, either in terms of settlement structure or the method of house construction. The observed continuity between the Nagyrév and the Vatya has also been underlined by extensive ceramic technological studies (Kreiter 2007, in press a).

In order to better understand change and continuity between Bronze Age communities and their economical and political organisation an excavation was launched at Százhalombatta in 1998, as part of the major international research project 'Emergence of European Communities: Household, Settlement and Territory in Later Prehistory' (http://www.eoec.org).

Samples

Ceramics

The examined ceramic samples belong to the Nagyrév and Vatya societies. Their macroscopic description is presented starting with the fine wares (consumption wares) followed by the coarse wares (household wares).

Sample 1 (inv. no. 99.54.2): A rim fragment of a small Vatya (Rákospalota type) jar (e.g. Kreiter 2005, Pl. 1.2, 2.3-4). It is decorated with two shallow horizontal incised lines. Below the lines there are horizontally arranged impressed dots. Above the lines the surface is decorated with hatched incised triangles and between the triangles there are horizontally arranged impressed dots. Both exterior and interior are elaborately burnished. The sherd is fully reduced, its core, exterior and interior has an even black colour. Wall thickness varies between 3 and 4 mm.

Sample 2 (inv. no. 98.23.43): A shoulder of a Nagyrév jar (e.g. Poroszlai 2000, Pl. XXIII.1-2), elaborately burnished with well defined striations made by a burnishing tool on both exterior and interior surfaces. The exterior of the sherd is oxidised exhibiting a light brown or orangey hue, while the interior is grey. Its core and interior are reduced. Wall thickness varies between 5-6 mm.

Sample 3 (inv. no. 98.144.2): A body sherd of a Nagyrév jar (e.g. Poroszlai 2000, Pl. XXIII.1-2). Its exterior is elaborately burnished with even surface and no burnishing marks are visible. Its interior is partly burnished and untreated. The core, exterior and interior are reduced, showing an even black colour. The exterior burnishing together with reduced firing conditions lend the surface a shiny lustrous appearance. Wall thickness varies between 4.5-5 mm.

Sample 4 (inv. no. 98.69.9): A rim fragment of a Vatya bowl with a pointed protrusion coming from the rim (e.g. Poroszlai 2000, Pl. XI.5, Kreiter 2005, Pl. 3.14). Its exterior and interior are elaborately burnished with an even surface and no burnishing marks are visible. The core, exterior and interior are reduced, showing an even black colour. Wall thickness varies between 4-5 mm.

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Sample 5 (inv. no. 97.115.67): A body sherd of a Nagyrév urn (e.g. Poroszlai 2000, Fig. 19). Its exterior and interior are elaborately burnished with an even surface and no burnishing marks are visible. The core and exterior are oxidised exhibiting an orangey hue. The interior is unevenly fired exhibiting a brownish hue and it is fire clouded. Wall thickness varies between 10-11.5 mm. The vessel was made by a slab technique which is indicated by overlapping slabs in the cross-section of the sherd.

Sample 6 (inv. no. 1377.1): A body sherd of a Vatya urn with brushed decoration (e.g. Bóna 1975, Taf. 52.7, 53.3). Within the shallow channels that were created by brushing, striations of a vegetal material can be observed. Brushing was applied to the surface after it was slightly burnished. The interior of the sherd is also burnished. The core, exterior and interior are reduced, the sherd exhibits brownish and greyish hues. Wall thickness varies between 8-8.5 mm.

Sample 7 (inv. no. 1377.2): A body sherd of a Vatya urn with brushed decoration (e.g. Bóna 1975, Taf. 52.7, 53.3). Within the shallow channels that were created by brushing, striations of a vegetal material are visible. Prior to brushing this vessel was not burnished. The interior of the sherd is untreated. The core, exterior and interior are oxidised, the sherd having a light brown hue. Wall thickness is 11 mm.

Sample 8 (inv. no. 1377.3): An upper body sherd of a Vatya urn with a small channelled knob decoration (e.g. Kreiter 2005, Pl. 3.2). The decoration was made by pressing the clay outwards from the inside then creating a smoothed channel around the small protrusion. The exterior and interior of the sherd are burnished. The cross section of the sherd exhibits a sandwich structure indicating that firing conditions were varied, although the exterior was reduced to black. Wall thickness is 6.8 mm.

Clay samples

Ten clay samples were obtained from the close vicinity of the settlement of Százhalombatta. The samples were collected by János Kalmár west from the tell mound, from the side of an Upper Pliocene escarpment (Kalmár 2005, 86 Map 1). The sampling locations are within approximately 20 metres of each other. The collected samples were different macroscopically and, by adding water, their plasticity was also found to be different and thus potentially useful for analyses. Samples K3/1, K3/2 and K3/3 are derived from a depth between 100 and 220 cm; samples K4/1 and K4/2 from a depth between 80 and 200 cm and samples K5/1, K5/2, K5/3, K5/4 and K5/5 from a depth between 135 and 185 cm. The depths of the clay samples were measured from the contemporary surface.

Methods

Ten clay samples and eight sherds were analysed by using polarising and cathodoluminescence (CL) microscopy, X-ray diffraction (XRD) and X-ray fluorescence (XRF) analyses.

Non-plastic inclusions in pottery and clay samples and textural characteristics of sherds were examined with a polarising microscope. The fabric recording suggested by the Prehistoric Ceramic Research Group (PCRG 1997) was used. Complementary cathodoluminescence microscopic analysis was performed on polished ceramic sherds on a RELIOTRON type cold cathode CL instrument mounted on a Nikon Eclipse 600 microscope.

Mineralogical composition of pottery and clay samples was determined by X-ray diffraction analysis. In the case of clay samples XRD investigation was carried out on both original and fired materials, for the latter the samples were formed into biscuits and fired in an electric kiln at 600 to 650ºC. XRD analyses were carried out on Philips PW 1730 diffractometer with a Bragg-Brentano alignment at the Department of Colloid Chemistry, University of Szeged and the Institute for Geochemical Research, Budapest. Instrument parameters: CuKα radiation, 45kV tension, 35 mA intensity, 0.05° - 0.01° 2Θ step size, time constant 1 sec, and graphite monochromator.

Major (Si, Ti, Al, Fe, Mn, Ca, Mg, K, and P) and trace element (Sc, V, Co, Ni, Zn, Rb, Sr, Y, Zr, Nb, Ba, La, Ce) contents of sherds and clay samples were determined by X-ray fluorescence analysis performed on a Philips PW 1410 fluorescence spectrometer. The major chemical components of the samples were normalised with the data of Post-Archean Australian Average Shale (Nance & Taylor 1976; Taylor & McLennan 1985; McLennan 1989, 2001).

Results

Petrography

Ceramic samples

Detailed petrological description of the sherds is presented in the Appendix. Sherds are characterised as being of very fine, very fine to fine and fine to medium-grained (very fine, very fine to fine and fine to medium sandy) (**Fig. 2a-h**). In the very fine-grained samples (samples 1-3) the grains are silt sized (0.1 mm <). The very fine to fine-grained samples (samples 6-8) mostly show grain sizes up to 0.25 mm, occasionally, however, medium-grained (0.25-1 mm) non-plastic inclusions also

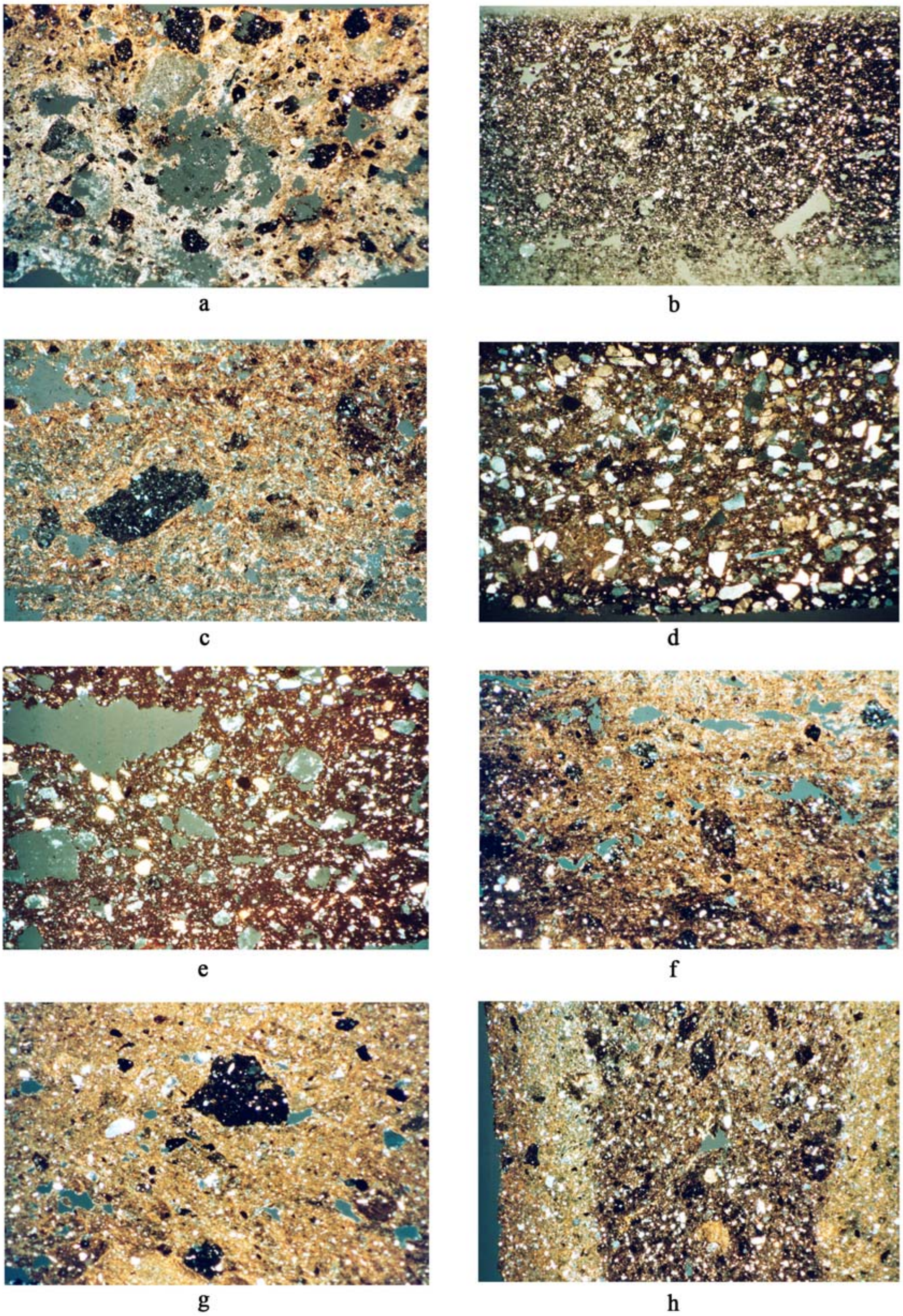

Figure 2. Microphotographs of ceramic thin sections from Százhalombatta

a: Vatya jar (sample 1), b-c: Nagyrév jars (samples 2-3), d: Vatya bowl (sample 4), e: Nagyrév urn (sample 5), f-h: Vatya urns (samples 6-8). Cross nicols, the longer side of the pictures for Figs. 2a-b and 2d-h is 6.8 mm, and for Fig. 2c is 3.4 mm.

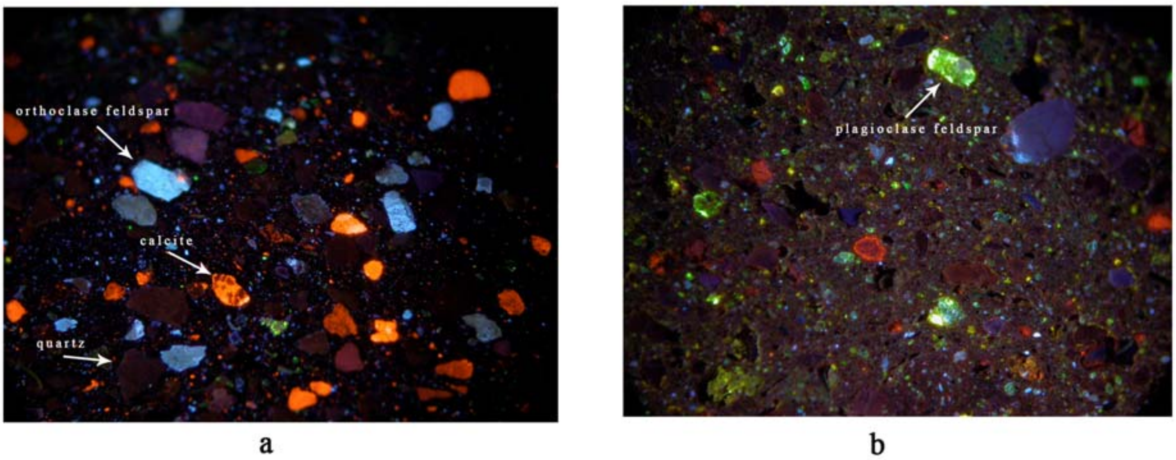

Figure 3.

CL microphotograph of polished ceramic cross-section

a: Vatya bowl (sample 4), b: Nagyrév urn (sample 5). Viewable area is 5 mm.

appear. Fine to medium-grained samples (samples 4-5) show grain sizes up to 1 mm.

The main non-plastic inclusion of the samples is angular to subangular very fine-grained monocrystalline quartz. In the Százhalombatta samples quartz grains have violet or brownish cathodoluminescence colours, suggesting igneous and metamorphic origin (Götze et al. 2001; Richter et al. 2003) (**Fig. 3a-b**).

The medium sized quartz grains tend to be polycrystalline. All samples exhibit rare or sparse amounts of white mica flakes. Limestone also appears in different amounts, although the roundness and even size distribution of the grains suggest that it was naturally present in the clays. Accessories of orthoclase and plagioclase feldspar, biotite, calcite, volcanic fragments, metasediment, chert, hypersthene, andesite and metasandstone are also present. Purposeful tempering is likely in six samples.

Sample 1 has clay pellets and argillaceous rock fragments that may have been purposefully added as temper (**Fig. 2a**). Samples 3 and 6 are tempered with rare amounts of medium to coarse grog. Sample 4 shows increased amounts of medium sized quartz and the fabric is hiatal, which may suggest that the clay was tempered with sand (**Fig. 2d**). Sample 7 shows grog temper and some argillaceous rock fragments (**Fig. 2g**) and even though the sample has decreased amounts of non-plastic inclusions, the size distribution of grains is hiatal suggesting that, apart from the grog and argillaceous rock fragments, a little amount of sand may also have been added to the clay as temper (**Fig. 2g**). Sample 8 also shows argillaceous rock fragments (**Fig. 2h**), which may have been added to the clay as temper. Samples 2 and 5 seem to contain naturally present non-plastic inclusions.

It must be noted that distinguishing between grog, clay pellets and argillaceous rock fragments is often difficult. In distinguishing between them characteristics of boundaries, roundness, shape, optical density, internal structure and colour were assessed as suggested by Whitbread (1981).

Clay samples

All of the clay groups contain increased amounts of calcareous inclusions in the forms of rounded to subrounded limestone and calcite. There are differences in the size ranges and amounts of calcareous inclusions: groups K3 and K4 have silt sized calcareous inclusions, while group K5 has very fine to medium sized inclusions. All of the clay groups exhibit sparse or moderate amounts of angular to subangular very fine to fine-grained monocrystalline quartz. Rare to sparse amounts of angular to subangular medium sized polycrystalline quartz are also present in groups K3 and K5. The samples also show rare or sparse amounts of very fine to fine-grained white mica flakes. There are also differences between the clay samples in terms of the range of non-plastic inclusions. For example clay group K3 and K5 exhibit rare amounts of polycrystalline quartz, biotite, orthoclase feldspar, plagioclase feldspar, zoisite-clinozoisite, volcanic fragments and glauconite, while group K4 does not shows such wide variability of minerals. Group K4 exhibits only biotite as an accessory mineral. Group K5 also has chert which was not observed in group K3.

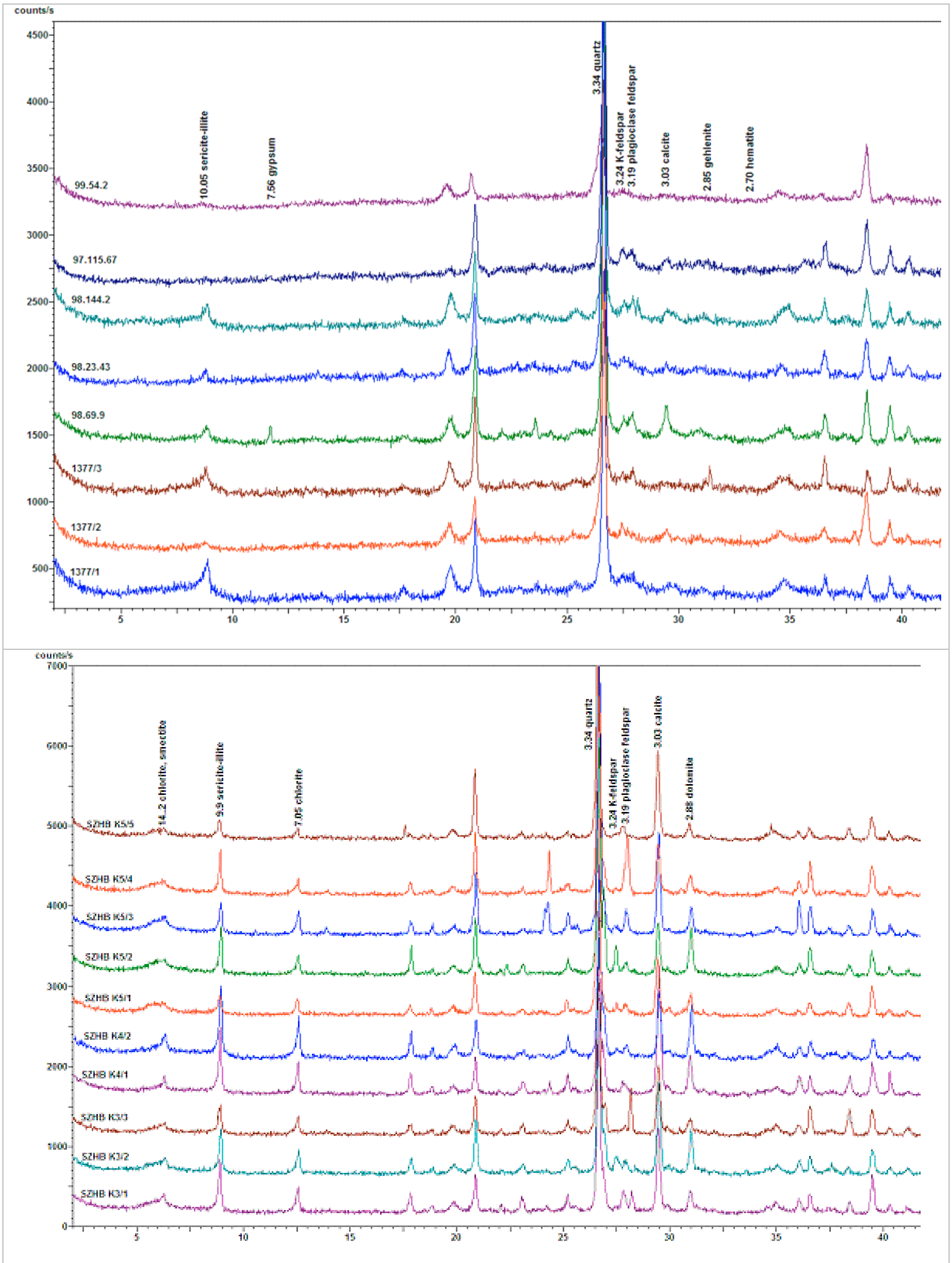

Figure 4a –b.

XRD profiles of the examined sherds (a) and unfired clay (b) samples from Százhalombatta.

Table 1.

Chemical composition of ceramic samples, a: major elements (in wt%), b: minor elements (in ppm)

Sample name	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	K_2O	P_2O_5	Total
98.23.43	53.56	0.74	15.61	5.44	0.05	1.13	1.47	3.34	0.22	81.55
1377/3	53.56	0.67	14.11	5.71	0.07	1.20	1.70	3.08	0.36	80.45
97.115.67	58.04	0.58	11.90	5.49	0.08	1.04	2.93	2.65	0.24	82.94
1377/1	48.78	0.71	15.43	6.06	0.05	1.46	1.12	3.67	0.19	77.47
98.144.2	47.26	0.64	16.12	4.48	0.05	1.10	2.35	3.91	0.30	76.21
98.69.9	57.10	0.44	13.04	2.74	0.05	1.17	4.85	3.02	0.27	82.69
1377/2	52.72	0.75	13.93	5.38	0.07	1.17	2.24	3.17	0.27	79.70
99.54.2	50.94	0.63	18.22	5.06	0.05	0.93	2.03	4.02	0.25	82.14

a

Sample name	Rb	Sr	Ba	Zr	Nb	Y	La	Ce	Sc	Co	Ni	Zn
98.23.43	169	134	470	192	23	47	47	73	18	18	73	147
1377/3	124	309	997	230	21	48	32	100	17	17	72	97
97.115.67	120	130	390	196	20	40	54	64	15	17	76	100
1377/1	160	136	457	154	18	42	36	71	18	20	102	114
98.144.2	159	150	389	173	20	50	35	61	19	14	62	114
98.69.9	120	191	311	154	25	35	24	51	13	9	56	85
1377.2	140	176	776	189	26	80	54	89	19	15	85	103
99.54.2	187	262	521	320	23	21	20	78	17	12	55	129

b

X-ray diffraction analysis

The ceramic samples are dominantly composed of quartz, and small amounts of plagioclase, K-feldspar, calcite, dolomite and 10 Å phyllosilicate were also detected (**Fig. 4a**). The (001) peak of chlorite (14 Å) is not present, which indicates that the sherds were fired above 650ºC (**Fig. 4a**). Residues of calcite in the ceramics suggest that the firing temperature did not exceed 800 to 850°C. In one ceramic sample (Sample 4, no. 98.69.9) gypsum (7.56 Å) also appears, probably as a result of post depositional process.

The clay samples are also mainly composed of quartz (**Fig. 4b**). K-feldspar and plagioclase feldspar, 10 Å phyllosilicates and chlorite are also characteristic. Each clay sample contains more calcite and dolomite than the sherds but the amounts vary. Sample group K5 contains less clay minerals than sample groups K3 and K4.

After firing clay samples at about 600 to 650°C a chlorite (002) peak at 7 Å usually disappeared and (001) a peak at 14 Å increased (except in sample K4/1). New Ca-silicate phases were not formed and more or less calcite remained in the fired samples. In many clay samples (K3.2, K3.3, K4.1, K5.1, K5.3 and K5.5) some dolomite could also be observed after firing. Dolomite starts decomposing at around 550 to 650ºC although the decomposition rate depends on the size of the grains (larger grains decompose more slowly than smaller grains) and the duration of burning. Dolomite is also present in the analysed sherds indicating that the original firing temperature of ceramics remained relatively low.

Chemical composition by X-ray fluorescence analysis

The major and minor chemical compositions (normalised to PAAS) are usually in the same range for the examined sherds (**Fig. 5a-b, Table 1a-b**). There are, however, exceptions in the amount of CaO, Fe_2O_3 and TiO_2. Sample 4 (98.69.9) exhibits the lowest TiO_2 and Fe_2O_3, and the highest CaO content (**Fig. 5a**), the latter being due to its high calcite and gypsum content observed by XRD analysis.

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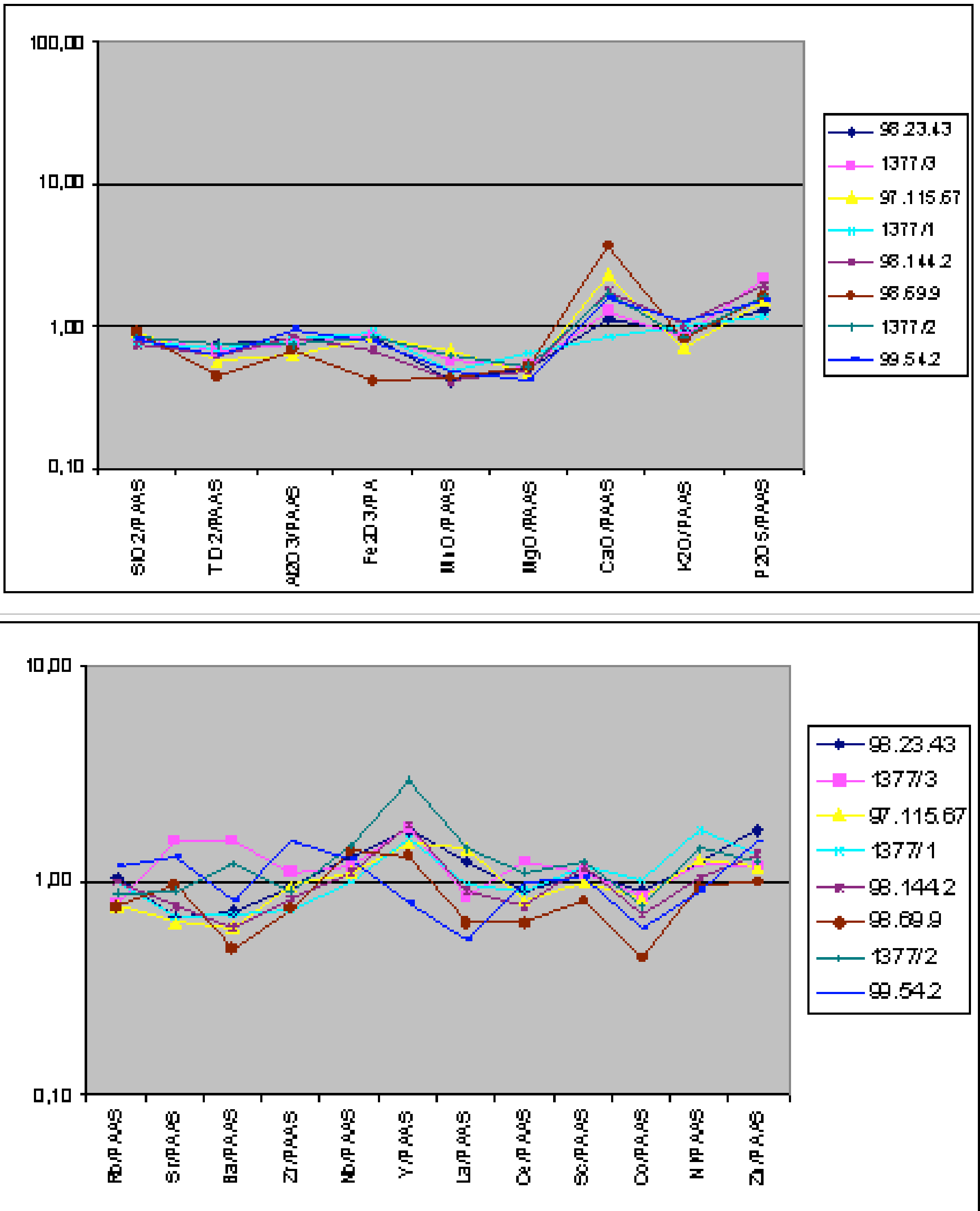


Figure 5.

Major (a) and trace (b) element composition patterns of sherds from Százhalombatta normalised to PAAS.

Apart from mobile elements (Rb, Sr, Ba) and in some cases Y the trace element patterns of the sherds are more or less similar to each other and the minor anomalies are not considerable. Sample 4 is poorer in trace elements compared to other samples.

For the clay samples from Százhalombatta the major chemical compositions (normalised to PAAS) are very similar to each other (**Fig. 6a, Table. 2a-b**).

Table 2.

Chemical composition of clay samples, a) major elements (in wt%), b) minor elements (in ppm).

Sample name	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	K_2O	P_2O_5	Total
SZHB K3/1	37.81	0.36	9.24	3.24	0.09	0.70	19.49	2.17	0.06	73.15
SZHB K3/2	45.21	0.42	10.11	3.58	0.07	0.66	13.69	2.23	0.12	76.09
SZHB K3/3	45.80	0.42	10.10	3.45	0.07	0.62	13.24	2.24	0.14	76.07
SZHB K4/1	36.14	0.35	9.09	3.24	0.11	1.02	19.06	2.45	0.05	71.52
SZHB K4/2	37.14	0.39	9.88	3.69	0.11	1.39	17.26	2.50	0.03	72.38
SZHB K5/1	53.67	0.34	8.71	2.67	0.06	1.34	11.27	1.79	0.17	80.02
SZHB K5/2	50.40	0.32	8.77	2.50	0.05	1.34	11.53	1.75	0.17	76.83
SZHB K5/3	49.77	0.32	8.35	2.63	0.06	1.38	11.75	1.82	0.18	76.27
SZHB K5/4	51.95	0.33	8.11	2.70	0.07	1.31	11.29	1.87	0.20	77.85
SZHB K5/5	50.16	0.34	8.15	2.56	0.06	1.35	10.44	1.91	0.24	75.21

a

Sample name	Rb	Sr	Ba	Zr	Nb	Y	La	Ce	Sc	Co	Ni	Zn
SZHB K3/1	74	220	178	142	18	26	20	37	17	9	38	63
SZHB K3/2	90	249	230	173	19	23	20	44	15	8	49	70
SZHB K3/3	93	265	226	165	23	25	20	42	11	10	37	65
SZHB K4/1	70	316	194	147	18	65	22	42	23	10	51	61
SZHB K4/2	75	269	207	144	18	31	27	40	21	9	47	62
SZHB K5/1	64	220	193	188	18	24	24	40	15	8	32	56
SZHB K5/2	63	215	188	159	18	26	21	38	12	9	31	50
SZHB K5/3	61	224	197	163	18	24	20	37	12	11	29	41
SZHB K5/4	74	212	206	149	18	65	20	39	13	10	29	46
SZHB K5/5	67	221	186	158	21	57	20	34	13	8	33	48

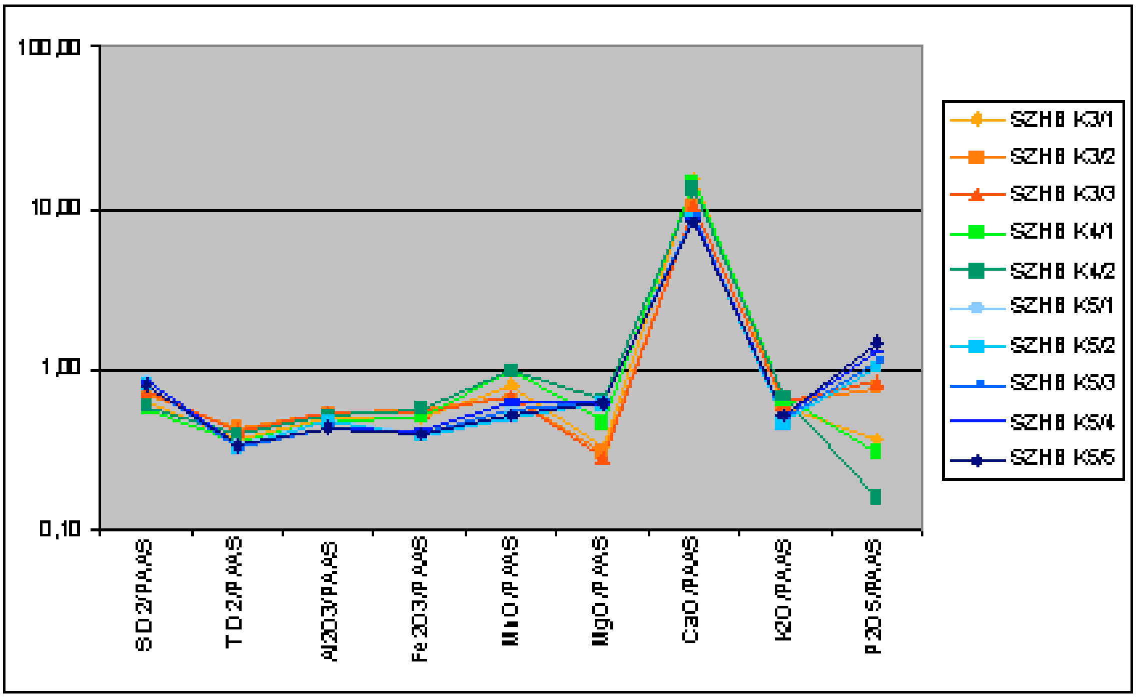
b

There are minor differences, however, in MgO and P_2O_5 content. Clay samples within K5 group hardly differ from each other and samples within K4 group are also similar although within the latter group there is a minor variation in P_2O_5 content. The composition patterns in sample group K3 show similar characteristics, but this group contains the least amount of MgO and its P_2O_5 content is between that of groups K5 and K4. The trace element concentration patterns of clay samples (normalized to PAAS) are also quite similar to each other (**Fig. 6b**). Y positive anomaly exists, however, in three samples (K4/1, K5/4, K5/5).

The major difference between the composition of ceramics and the collected clay samples is in their CaO content. The amount of CaO is considerably smaller in the sherds (1.1 to 4.9 wt%) compared to the clays (10.4 to 19.5 wt%). This is well illustrated in a CaO+MgO – SiO_2 – Al_2O_3 ternary diagram (**Fig. 7**), where ceramics show a little difference in Al/Si ratio from each other, but clays are more divergent from ceramics due to their higher alkaline earth metal content. This difference can be attributed to the higher carbonate (calcite, dolomite) content of the collected clay samples compared to the examined sherds. The ternary diagram also shows that most of the ceramics have slightly higher Al_2O_3 content than local sediments (clay).

Discussion

The selection of clays and tempers as part of technological choices plays an important role in pottery studies. The importance of petrological analysis in this study is that it indicates that there are differences between different vessel types in terms of clays and tempers and it also shows that similar vessels could also be made differently.



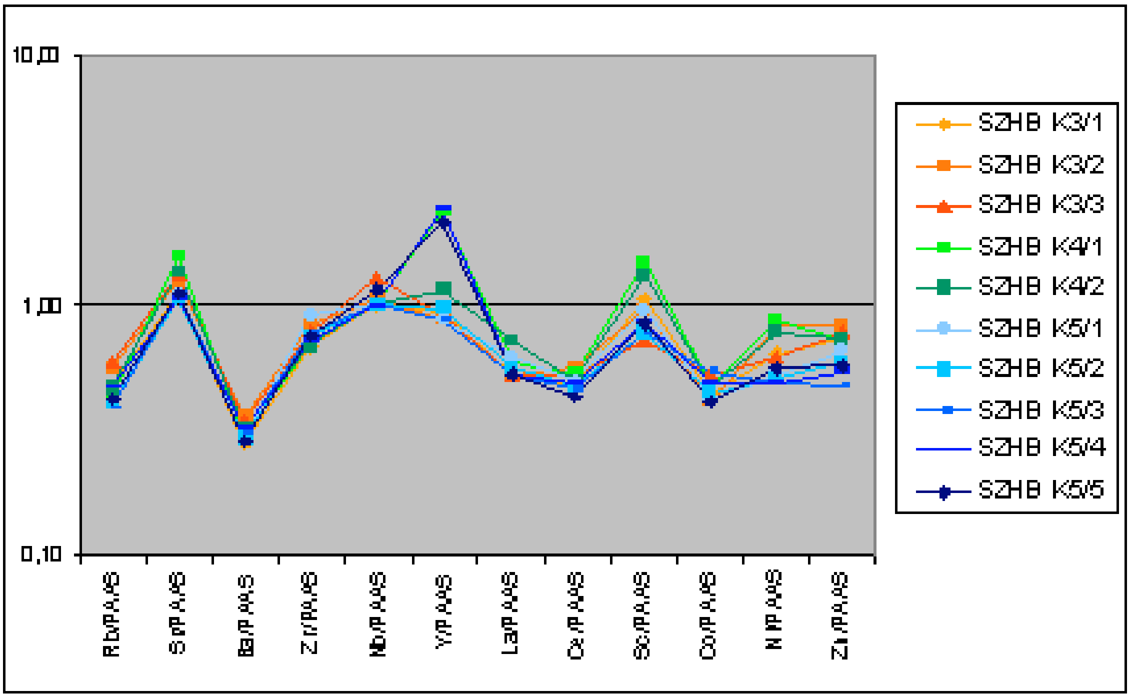


Figure 6.

Major (a) and trace (b) element composition patterns of clay samples from Százhalombatta normalised to PAAS.

For example a Vatya jar (sample 1, **Fig. 2a**) was made from a different clay from a Vatya bowl (sample 4, **Fig. 2d**) and the raw materials of these consumption wares also show differences from the composition of household wares such as urns. It is also observable that similar vessel types (samples 2-3, Nagyrév jars, **Fig. 2b-c**) show pronounced differences in the amount of very fine quartz (very fine sand) and sample 3 was also tempered with grog while sample 2 was not. Samples 6-8 (Vatya urns, **Fig. 2f-h**) also show differences in terms of tempering because sample 6 was tempered with

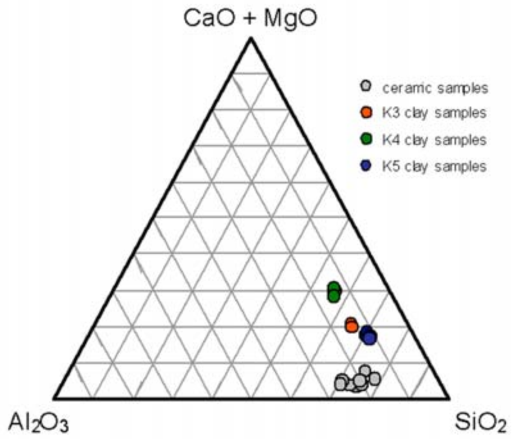


Figure 7.

Chemical composition of the examined sherds and clay samples from Százhalombatta in a CaO+MgO – SiO_2 – Al_2O_3 triangle diagram.

grog, sample 7 was tempered with grog, argillaceous rock fragments and sand, and sample 8 seems to be tempered with argillaceous rock fragments. These observations suggest either that different clays were used to make similar vessels or that similar clays were treated differently.

Examination of clay samples by the same methods as the sherds suggest that even though there is some variation in the composition of the clay samples, all the clay types could have been potential raw materials for potting. XRD and XRF analyses together suggest that there is no reason to believe that the examined ceramic samples were made from non-local clays. Differences were observed between ceramics and clay samples in the absence of chlorite and in the amount of carbonate due to firing. Higher CaO content in the studied clay samples than in the sherds revealed by XRF study can be attributed to a higher amount of carbonate (calcite, dolomite) in the clays. The high carbonate content of the clay samples is not considered to be due to secondary carbonate enrichment because there are similarities in the calcareous inclusions between the sherds and clay samples in terms of the size and roundness of limestone inclusions. In spite of that sherds show less CaO and higher Al_2O_3 content than the clay samples.

Even though XRD and XRF analyses indicate similarities between the sherds and clay samples in terms of their composition, it must be emphasised that even if any of the examined clay types were used for potting they had to be altered, for example by mixing them with a different type of clay, which resulted in the decrease of calcareous inclusions or they had to be prepared differently by eliminating some of the calcareous inclusions. Alternatively potters may have used different locally available raw materials with decreased calcareous inclusions. It has already been noted that the sherds have higher Al_2O_3 content than the clay samples. Moreover, immobile trace elements show similar distribution in the sherds to clay samples, even though their amount in the sherds is higher than in the clays. One possible explanation of this phenomenon is that the raw materials of the sherds are richer in clay minerals than the examined clay samples. It is also a possibility that potters used other locally available clay types rather than the ones examined in this paper, and those clays were richer in clay minerals or, alternatively, potters mixed their raw materials with other clay types that were richer in clay minerals. If the potters at Százhalombatta chose other clay types from the ones examined in this paper, they must have been situated close to those clays examined in this paper, or at the least have been available locally since the petrological and chemical characteristics of the sherds and clays are similar. In sample 6 a possible mixing of clay is suggested by petrographic analysis. Mixing of clays of different qualities is often reported in ethnographic examples (Sillar 1997, 11).

XRD results indicate that the firing temperature of the sherds stayed between 650 and 850ºC. This is consistent with firing temperatures usually evaluated for Bronze Age pottery. Investigation of Bronze Age firing temperatures of Nagyrév (Tószeg) and Gyulavarsánd (Berettyóújfalu) ceramics also concluded that the vessels were fired at temperatures less than 800 ºC and most likely around 700 ºC (Maniatis & Tite 1981). Examination of Maros ceramics also shows that at Kiszombor and Klárafalva the firing temperatures of the vessels remained under 800 ºC all through the Early and Middle Bronze Age (Michelaki 1999, 231). Similar estimations were made on Late Bronze Age pottery from Isztimér-Csőszpuszta (Szakmány–Kustár 2000, 56), Németbánya, Nagydém and Velem (Varga et al. 1988, 31; Gherdán 1999, 105-106).

Summary

In this study the technological characteristics of both household wares and highly distinctive consumption wares were examined. Consumption wares from the Koszider period (samples 1, 4 and 8) often exhibit complex and elaborate decorative motifs, surface processes and firing techniques showing distinct technological characteristics (Kreiter 2005). Despite their distinctiveness the composition of these wares has never been investigated. The similarities in terms of mineral phase and raw material composition seen in our results suggest that the production of highly elaborate vessels was local (even the Rákospalota type ware) rather than being centralised. Petrological analysis shows that there is variability amongst the vessel types in terms of the range and amount of non-plastic inclusions. Part of the importance of petrographic analysis in this study is that it provided data on the actions taken by potters in the fabrication of vessels. The mineralogical data show the presence or absence of a particular type of temper or amount and size differences between similar non-plastic inclusions. Thus even if the main composition of the vessels is similar petrographic observations suggest that they were probably made from different clays from the local environment or that similar clays were treated differently. These practices have important implications for the understanding of Bronze Age pottery production and distribution. Although no ceramic production locality is known either from Százhalombatta or from other Bronze Age sites in Hungary, different technological patterns suggest the existence of many potters (Kreiter in press a; in press b). The technological characteristics of different vessel types, in particular the black burnished Koszider fine wares, also suggest different skills in pottery production, which in turn indicates distinctions between potters and their products (Budden 2002). However, it is clear that more research is needed to assess the extent of possible specialisation within a particular vessel type. Notwithstanding, the results of this study suggest that in the process of material culture production, technological choices are also an essential part of complex, dynamic social strategies. Such strategies may exist both between people, and between people and the environment from which they will draw their resources.

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Appendix

Petrological description of sherds

Sample 1 (inv. no. 99.54.2) (Fig. 2a): The thin section exhibits sparse amounts of angular to subangular very fine-grained monocrystallyne quartz; rare amounts of very fine muscovite flakes and rare amounts of medium sized polycrystalline quartz, plagioclase feldspar, biotite and limestone fragments can also be observed. There are sparse amounts of coarse-grained clay pellets (light brown) and moderate amounts of fine to medium sized argillaceous fragments (black). Some of the characteristics of the black inclusions such as boundaries, roundness, shape and optical density show similarities to grog but the internal feature of the grains show weak orientation and they seem very compact and dense. For this reason the above mentioned black inclusions are considered to be argillaceous rock fragments rather than grog. In this sample the hiatal size distribution of clay pellets and argillaceous rock fragments suggest that they may have been purposefully added to the clay as temper.

Sample 2 (inv. no. 98.23.43) (Fig. 2b): The thin section shows common amounts of angular to subangular very fine-grained monocrystalline quartz; sparse amounts of very fine muscovite flakes and rare amounts of biotite and plagioclase feldspar. The observable non-plastic inclusions were probably naturally present in the clay and no purposefully added tempering material can be observed.

Sample 3 (inv. no. 98.144.2) (Fig. 2c): There are sparse amounts of angular to subangular very fine monocrystalline quartz, sparse amounts of very fine muscovite flakes and rare amounts of biotite and calcite. In this sample naturally present clay pellets are observed that are rounded and show diffuse or merging boundaries. There are also rare amounts of medium to coarse, subrounded to subangular grog. The observable non-plastic inclusions were probably naturally present in the clay and apart from the grog no purposefully added tempering material can be observed.

Sample 4 (inv. no. 98.69.9) (**Fig. 2d**): The thin section exhibits moderate amounts of angular to subangular fine-grained monocrystalline quartz; sparse amounts of angular to subangular medium sized quartz; moderate amounts of fine to medium rounded to subrounded limestone fragments and rare amounts of very fine to fine muscovite flakes. Rare amounts of chert, plagioclase feldspar, orthoclase feldspar, biotite, hypersthene and metasediments can also be observed. Clusters of fine-grained muscovite mica are also present. In this sample the observable non-plastic inclusions show higher variability than in the previous samples. Moreover inclusions such as andesite would suggest a non-local origin of the vessel. However, the roundness and fine nature of inclusions does not suggest purposeful crushing of rocks for tempering. These inclusions were probably part of the clay or may have been part of a river sand that potters used for tempering. The hiatal size distribution of grains may indicate a use of sand for tempering.

Sample 5 (inv. no. 97.115.67) (Fig. 2e): The thin section shows common amounts of angular to subangular very fine monocrystalline quartz; rare amounts of angular to subangular fine monocrystalline quartz; sparse amounts of angular to subangular medium sized monocrystalline and polycrystalline quartz; sparse amounts of fine to medium, rounded to subrounded limestone fragments and rare amounts of very fine to medium sized muscovite flakes. Rare amounts of chert, plagioclase feldspar, orthoclase feldspar, biotite, zoisite-clinozosite, metasandstone can also be observed. The observable non-plastic inclusions were probably naturally present in the clay and no purposefully added tempering material can be observed.

Sample 6 (inv. no. 1377/1) (Fig. 2f): There are sparse amounts of angular to subangular very fine monocrystalline quartz; rare amounts of angular to subangular fine monocrystalline quartz; rare very fine-grained muscovite flakes and rare amounts of subrounded to subangular medium to coarse-grained grog. Rare amounts of chert, volcanic fragments, limestone fragments, clay pellets and orthoclase feldspar can also be observed. Clay pellets show clear, diffuse or merging boundaries and they are mainly rounded while grog shows clear boundaries and more angular features. In the thin section lighter and darker parts can be observed in the clay matrix. For this reason it can be assumed that the vessel may have been made by mixing two types of clays. In this sample grog was used for tempering and the other observable non-plastic inclusions were probably naturally present in the clay.

Sample 7 (inv. no. 1377/2) (Fig. 2g): There are sparse amounts of angular to subangular very fine monocrystalline quartz; rare amounts of angular to subangular fine monocrystalline quartz; rare amounts of very fine-grained muscovite flakes and rare amounts of very fine to fine-grained, rounded limestone fragments. Rare amounts of biotite, plagioclase feldspar, orthoclase feldspar and rare amounts of medium to coarse, subangular to subrounded grog can also be observed. There are also sparse amounts of mainly fine argillaceous rock fragments that seem very dense and compact.

Sample 8 (inv. no. 1377/3) (Fig. 2h): The thin section exhibits moderate amounts of angular to subangular very fine-grained monocrystalline quartz; sparse amounts of angular to subangular fine quartz; rare amounts of very fine muscovite flakes and rare amounts of very fine to fine rounded limestone fragments. Sparse amounts of subrounded to rounded mainly fine to medium argillaceous rock fragments are also present. Their boundaries are clear or diffuse and their internal feature shows weak orientation and they seem very compact and dense. This sherd also shows fine textured inclusions with igneous origin such as andesite fragments. Rare amounts of chert and low grade metasedimentary rock fragments can also be observed. The roundness and fine nature of volcanic fragments does not suggest purposeful crushing of rocks for tempering but rather they were probably part of the clay or alternatively may have been part of river sand that potters used for tempering.

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