THE BALTIC IN THE BRONZE AGE

Regional patterns, interactions and boundaries

edited by
Daniela Hofmann, Frank Nikulka
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A publication of the Institute for Pre- and Protohistoric Archaeology (Institut für Vor- und Frühgeschichtliche Archäologie) of the University of Hamburg.

Universität Hamburg
DER FORSCHUNG | DER LEHRE | DER BILDUNG

Published by Sidestone Press, Leiden
www.sidestone.com

Lay-out & cover design: Sidestone Press

Photographs cover:
Front: weststrand on the Fischland-Darß peninsula (Ariana Rama | stock.adobe.com);
Drawings: Nordic full-hilted sword from Asnæs Åstofte and octagonal-hilted sword from Niløse Kongsted (Aner, E. and Kersten, K. 1976. *Die Funde der älteren Bronzezeit des nordischen Kreises in Dänemark, Schleswig-Holstein und Niedersachsen*. Neumünster: Wachholtz, plates 29&20).
Back: mixed pine and deciduous forest, Lithuania (MNStudio | stock.adobe.com).

ISBN 978-94-6427-018-1 (softcover)
ISBN 978-94-6427-019-8 (hardcover)
ISBN 978-94-6427-020-4 (PDF e-book)

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Preface and Acknowledgements

This volume is the result of a 2017 workshop and a 2018 conference on the theme of circum-Baltic interactions, held at the University of Hamburg and kindly funded by the Behörde für Wissenschaft, Forschung und Gleichstellung (Ministry of Science, Research and Equality) of the Free and Hanseatic City of Hamburg. The majority of the papers collected here were first presented at these events, with a few contributions invited subsequently to fill thematic or regional gaps. At this point, we would like to thank all participants in the workshop and conference for sharing their ideas, the engaging discussions and the enthusiasm they have brought to the project. Thanks are also due to Hamburg University for the administrative support and to the many students who helped with the practical running of both events. All authors are thanked for their patience while this volume slowly neared fruition.

At Hamburg University, we would also like to express our gratitude to Paulina Kiel, who proved an invaluable help in all matters bibliographical, as well as Jeffrey König for his assistance with the figures. Finally, we are enormously indebted to the many colleagues who generously donated their time to provide peer reviews: Marja Ahola, Johann Arntzen, Richard Bradley, Dirk Brandherm, Alexandra Gavan, Svend Hansen, Anthony Harding, Christian Horn, Janne Ikaheimo, Mateusz Jaeger, Christoph Jahn, Aivaras Kareiva, Matt Knight, Chris Knüsel, Lene Melheim, Stuart Needham, Kamil Niedziółka, Courtney Nimura, Heide Wrobel Nørgaard, Grzegorz Osipowicz, Tomas Rimkus, Oula Seitsonen, Helle Vandkilde, Andrejs Vasks and Danuta Żurkiewicz. Thank you!

At Sidestone, we would like to thank Monica Huisman, Eric van den Bandt and Karsten Wentink.

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From the seaside to the inland

Comparing Late Bronze Age pottery production and styles in the eastern Baltic

Vanda Visocka, Vytenis Podėnas, Uwe Sperling

Introduction

The eastern Baltic Bronze Age has for a long time been distinguished for its role in interregional communication and exchange networks, and mainly from the perspective of metalwork trade relations. As the amounts or numbers of metal finds from hoards and graves from this period are modest compared to regions of the Nordic Bronze Age, this role was understood as passive or marginal (Sidrys and Luchtanas 1999). However, peripheral territories of the Nordic Bronze Age world have yielded some of the most intriguing cases of production sites (Earle *et al.* 2015; Jaanusson 1981; Melheim *et al.* 2016) and these have provided impulses for further development of the surrounding regions. The eastern Baltic coast is a case of a similar process, as the most diversified production sites are located in coastal areas (Podėnas and Čivilytė 2019). This article approaches the problem by investigating people's behaviour in pottery production technologies, one of the most common household practices.

Both metal objects and ceramics generally play a minor role in funerary customs of the east Baltic, i.e., are barely found in graves or hoards during the entire Bronze Age. The material culture of this period consists mainly of settlement finds, which are, overall, rich and comprehensive, but unevenly represented by mostly Late Bronze Age fortified settlements (LBA, c. 1100-500 cal BC; Podėnas 2020). That is the time when fortified settlements emerged in the east Baltic region, usually with thick cultural layers containing abundant archaeological and ecofactual data.

Over the last two decades, research progress concerning settlement remains, as well as bronze or pottery production, has resulted in a better understanding of the economic strategies, technical logistics and social relations of the craftsmen and individuals involved (e.g. contributions in Fokkens and Harding 2013; Orton *et al.* 1993; Ringstedt 1992; Woltermann *et al.* 2019). Abandoning the uninspiring view of the south-eastern Baltic's passive role in the exchange of metal objects, a more productive approach would be to look at the region as a unique case of society reacting to late and strong impulses of European intensive agriculture (Lang 2007; Minkevičius *et al.* 2020) and Bronze Age economy (Čivilytė 2014; Podėnas and Čivilytė 2019; Sperling 2014; Vasks 2010). Thus, this is an active territory of people exploring new ideas and adopting them to different degrees.

The study of pottery production is a further step towards understanding the social significance of both stylistic and material patterns. The focus of this paper is on the latter aspect: we will analyse and discuss similarities and differences among LBA groups of eastern Baltic pottery, as well as view pottery as a communication medium. Fortified settlements were mostly widespread on the hilltops and promontories of higher terraces, with concentrated enclosed habitational areas (Graudonis 1967; 1989; Grigalavičienė 1995; Lang 2007; Luchtanas 1992). This kind of site contained most of the communities'

In D. Hofmann, F. Nikulka and R. Schumann (eds) 2022. *The Baltic in the Bronze Age. Regional patterns, interactions and boundaries*, Leiden: Sidestone Press, pp. 161-188.

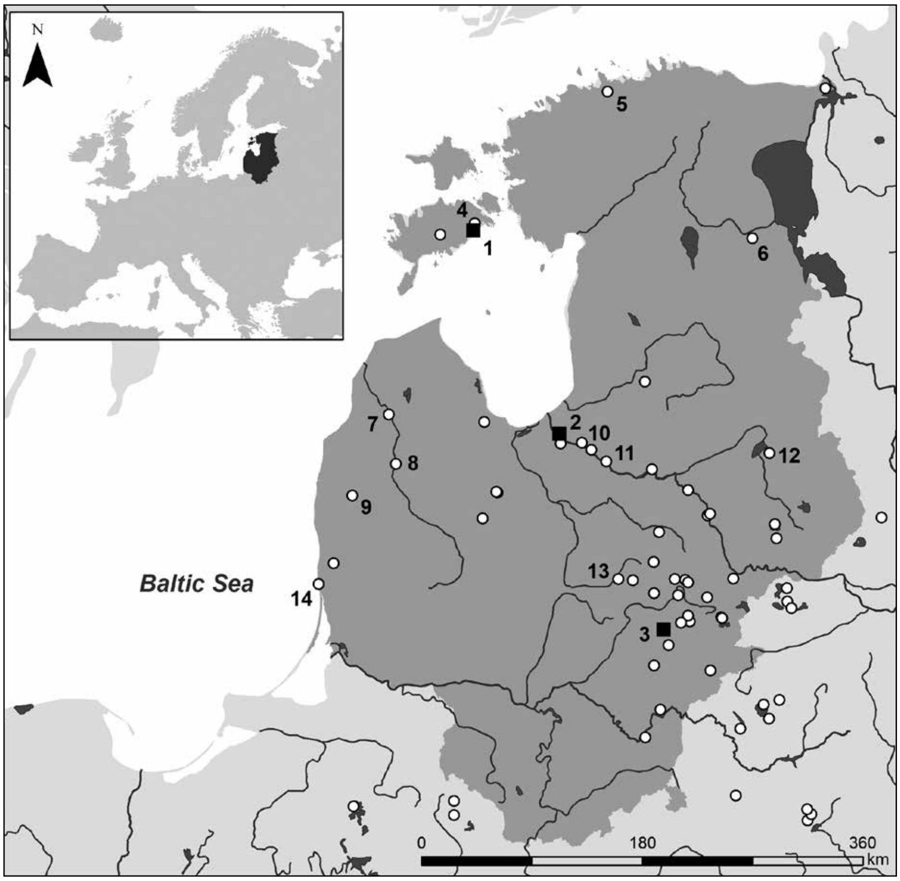

Figure 1. Map of fortified settlements mentioned in the text: 1 Asva, 2 Ķivutkalns, 3 Narkūnai, 4 Ridala, 5 Iru, 6 Kõivuküla, 7 Padure, 8 Krievu kalns, 9 Paplaka, 10 Vīnakalns, 11 Dievukalns, 12 Brikuļi, 13 Kupiškis, 14 Kukuliškiai. The unnumbered dots are other fortified settlements in the eastern Baltic; see Appendix 1 for a complete list of all 65 sites (figure: V. Podėnas).

refuse which accumulated due to the prolonged usage of a limited living area. The three archaeological assemblages chosen for this study were acquired from the fortified settlements of Asva (Estonia), Ķivutkalns (Latvia) and Narkūnai (Lithuania), which are among the most representative sites of the eastern Baltic Late Bronze Age in terms of amounts of finds per site. These sites reflect technologies used in three different ecotones: coastal, island along the river c. 25 km from the sea, and inland near a small stream, c. 200 km from the sea (Figure 1). Our paper aims to identify and compare the technological and stylistic traits of pottery production in these three cases as representative of three different ecological and economic environments in the eastern Baltic.

Background of the sites

Asva

The fortified settlement of Asva is located c. 3 km inland from the south-eastern shore of Saaremaa island (Estonia), but was at the time of its occupation partly surrounded by sea, small islets and brackish water lagoons. The site is situated on a moraine rising up to 5 m from the surrounding flat terrain of the island. Archaeological research was carried out in the 1930s, 1940s and 1960s and again since 2012. The excavations all took place on the edges of the c. 3500 m^2 elongated plateau, mainly in order to investigate the site's stratigraphy and the remains of defensive works (Sperling *et al.* 2019).

The site, leaving thick cultural layers alternating with burning horizons, has been in use some time between 900 and 500 BC based on the finds' typochronology (e.g. pottery and bronze finds; Montelius periods V-VI) and the radiocarbon dates, which span from

917 to 396 cal BC[1] (Sperling 2014; Sperling *et al.* 2015). During the LBA, the Asva site was only temporarily enclosed with a stone wall or fence, but an earthwork and wooden constructions were erected during the Pre-Viking period (600-800 AD; Sperling *et al.* 2019).

The amount of archaeological finds from at least two subsequent LBA habitation phases is remarkable, as only one fifth of the area of the settlement plateau (c. 600 m^2) has been investigated. More than 50,000 pottery fragments, c. 2000 fragments of clay casting moulds and c. 800 bone and antler artefacts testify to intense activities of consumption and production. The rich assemblages of animal bone demonstrate animal husbandry (sheep, cattle, pig, horse, dog) and a seasonal specialisation in hunting seals (grey, ringed, harp and harbour seal; Sperling 2014; Sperling *et al.* 2020).

The style and manufacture of household pottery has common traits with material from many Bronze Age settlements in the eastern European forest belt and has indeed similarities in the pottery of contemporary sites in the east Baltic (such as Ķivutkalns and Narkūnai). This also applies to the spectrum of bone and antler objects (Luik 2013; Luik and Maldre 2007). There is but one particular feature in the LBA Asva pottery, that of bowls and smaller cup-like vessels with characteristic handles and applications that show a different temper, surface treatment and decor than the coarse household vessels. The Asva bowls share similar traits with the late Urnfield culture milieu in eastern central Europe, possibly transmitted via southern Sweden and Gotland (Eriksson 2009; Sperling 2014). Nordic influences are also visible in the metalwork production of the Asva settlement. The vast majority of the casting debris (clay moulds) documents a preference for manufacturing ring-shaped objects (ingots?), but a number of preserved casting moulds also indicate that Nordic-type garment pins, spearheads and socketed axes were among the items produced at Asva (Sperling 2014).

Ķivutkalns

Ķivutkalns fortified settlement was established on Dole island, located in the river Daugava, on a promontory reaching a height of 10 m on that part of the shore and 3 m above the rest of the surroundings (Brastiņš 1930, 15). The promontory was surrounded by the small river Pižaga and its former distributary (Graudonis 1989, 11). Archaeological excavations led by Jānis Graudonis and Jolanta Daiga took place from 1966-1967 (Graudonis 1989, 11). Due to the construction of the Rīga Hydroelectric Power Plant, in whose flooding area Ķivutkalns was situated, the site was fully excavated, over a total area of 2276 m^2 (Graudonis 1989, 11-12). Notably, a cemetery with 247 inhumations and 21 cremations was discovered under the Ķivutkalns fortified settlement, making it a unique Late Bronze Age archaeological site with both burial and residential evidence (Denisova *et al.* 1985, 10).

The archaeological assemblage from the fortified settlement consists of a stray bronze bracelet found in 1942 and excavation finds, which include approximately 38,000 pottery fragments, 2700 other artefacts and 11,600 animal bones (Graudonis 1989, 11, 20). Most of the artefacts were made of stone and bone. Diagnostic LBA finds include various types of bronze and bone dress pins, including bronze pins with a loop, analogous to those from the Lusatian and West Balt Barrow cultures (Vaska 2019, 31), bronze socketed axes, bronze bracelets, ceramic casting moulds for KAM type axes and neck rings, as well as bronze, amber and antler double buttons and pottery (Graudonis 1989, 20-51, 147-48). Notably, there are also two hoards from Ķivutkalns, which include various bronze items – a socketed axe, a spiral pin with flat head, tutuli and neck rings with bent ends (Graudonis 1989, 41; Urtāns 1977, 40). These finds, according to Baiba Vaska (2019, 32), are artefact types typical for Scandinavia, east Prussia, Lithuania and Poland (see also Graudonis 1989, 41).

1 Throughout this paper we are using radiocarbon dates with 95.4 % probability (2 σ).

Based on these finds and ^{14}C analysis of charcoal, Graudonis distinguishes several inhabitation periods in Ķivutkalns: the first to third "layers" are dated to the second half of the first millennium BC, the fourth to sixth "layer" to the second half of first quarter and the second quarter of the first millennium BC, while the seventh to ninth/tenth "layer" span the beginning of the first millennium BC (Graudonis 1989, 21). However, these horizons were distinguished artificially following intuition, and thus do not represent a true stratification. A more precise chronology for the inhabitation period of the settlement was established using ^{14}C dates on bones and charcoal in 2013 and 2014. Based on the interpretation of these results, the inhabitation of the Ķivutkalns fortified settlement began in approximately 650 cal BC and continued periodically until the Pre-Roman Iron Age[2] (Oinonen *et al.* 2013; Vasks and Zariņa 2014).

Narkūnai

Narkūnai fortified settlement was established on a promontory reaching 14 m above its immediate surroundings and located c. 60 m from the Utenėlė rivulet. The promontory was surrounded by a smaller unnamed stream to the west. It was hypothesised that during the establishment of the medieval hillfort in the thirteenth to fifteenth centuries AD the promontory was further isolated by a 14 m deep ditch (Vengalis *et al.* 2020a). Therefore, it is difficult to determine whether the Late Bronze Age site was established on a terrace spanning 55x35 m (Baubonis and Zabiela 2005, 244) or on a significantly longer promontory of at least 125 m. The site was intermittently excavated by antiquarians from 1835 to 1912 (Podėnas *et al.* 2016, 193), and in 1976-1978 an area of 660 m^2 was investigated by a scientific expedition led by Regina Volkaitė-Kulikauskienė and Aleksiejus Luchtanas (Volkaitė-Kulikauskienė 1986).

The archaeological collection acquired during the 1976-1978 investigations included 12,047 pottery fragments, over 800 other artefacts and over 7000 animal bones (Baubonis and Zabiela 2005, 244; Podėnas *et al.* 2016, 204). Diagnostic LBA finds include ceramic casting moulds for KAM type axes and ring-shaped objects (Luchtanas 1981), bronze pins with analogies to Majków-type pins (Čivilytė 2014, 110-11), denoting long-distance contacts, a double button made from antler (Luik and Maldre 2007, 12) and several types of bone pins (Podėnas *et al.* 2016, 201, pav. 4:2-4). Based on the typical profiles of rim sherds, c. 66 % of the pottery could be attributed to the LBA (Podėnas *et al.* 2016, 205). The chronology of the LBA horizon was further narrowed down to 796-550 cal BC by a ^{14}C date on an *Ovis aries*/*Capra hircus* tibia (Podėnas 2020). This bone had been collected in the near vicinity of the earliest enclosure. Recently, an additional six AMS ^{14}C dates were acquired from charred organic residues in pottery and all of them have been calibrated to a range between 798 and 268 cal BC. During the LBA, the site was encircled by a wooden palisade, indicated by two to three lines of small postholes that surround the site. After the LBA horizon, the promontory was settled again from the first century BC to the second century AD and in the thirteenth to fifteenth centuries AD (Podėnas *et al.* 2016; Volkaitė-Kulikauskienė 1986).

Material and methods

The condition of the pottery assemblages in all three studied settlements is good. Assemblages mainly consist of sherds, only a few whole vessels were recovered. For further morphological and stylistic analysis, sherds with specific criteria were used as follows: known context (trench, layer, approximate date), distinguishable surface treatment, shape and wall thickness. Pottery fragments with known coiling technique and rim diameter, as well as ornamentation were also studied. For statistical analysis,

2 Three iron knives were found in the upper layers of Ķivutkalns, indicating possible temporary inhabitation around the second century AD (Graudonis 1989, 49). However, there are no other finds, including pottery, which indicate a settlement phase at that time.

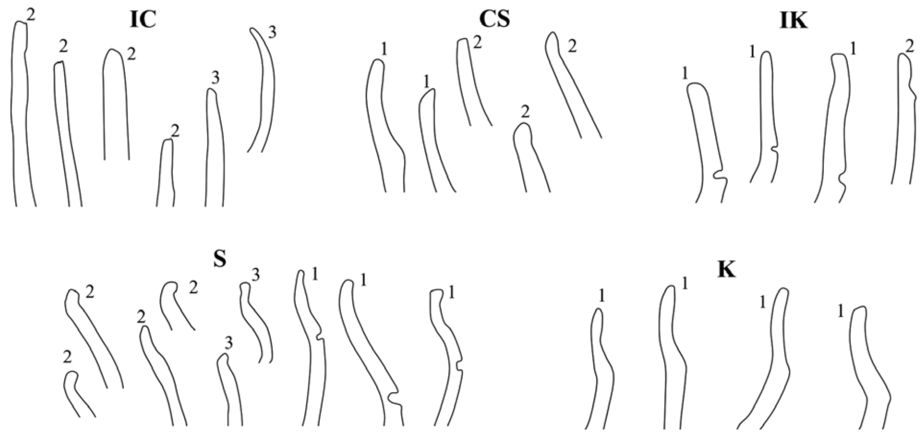

Figure 2. Common vessel rim profile shapes. 1 – Asva, 2 – Ķivutkalns, 3 – Narkūnai (figure: V. Visocka).

sherds of the same vessel were counted as one unit. Overall, 667 units from Asva, 387 form Ķivutkalns[3] and 934 from Narkūnai were studied in detail.

In order to group the material and analyse pottery morphology, the rim profile shape classification developed by Rimutė Rimantienė, with few alterations made by Andrejs Vasks and Vanda Visocka was used in this study (Rimantienė 2005, 45; Vasks 1991, 21-22; Visocka 2020, 86). Accordingly, the rim shapes of the vessels are grouped as follows: IC – barrel-shaped vessels with slightly curved or straight rim as well as those with almost conical body; CS – slightly profiled vessels with short cylindrical or inturned neck; S – strongly profiled vessels with everted rim; IK – semi-biconical vessels with a sinuous profile, vertical rim and soft break on the neck; K – biconical vessels with strong break on the neck (Figure 2).

However, in the case of Asva fine ware the classification developed by Uwe Sperling was used. Accordingly, we used the subdivisions of his type B vessels, whereby bowls are divided into I – with slightly curved rim and rounded break; II – with open rim, angular or rounded curve, weak or classical S profile; III – with curved rim and angular break on the neck part; IV – with long and vertical rim; V – curved rim and rounded break and VI – with open rim (Sperling 2014, 187).

Ceramic petrography

In order to study ceramic fabric in detail, petrography, using thin section analysis under a polarizing microscope, was used (for a detailed description of the method see Braekmans and Degryse 2016; Quinn 2013). Using this method, 57 samples were analysed (20 from Asva, 19 from Ķivutkalns[4] and 18 from Narkūnai; see Appendix 2). Pottery samples for petrographic analysis were chosen by the principle of known context and representativity. Accordingly, the Asva samples consisted of seven fine (polished) and 13 coarse sherds (six with striated surface, five smooth, one textile and one striated-textile); for Ķivutkalns ten striated, five smooth, three textile and one striated-rusticated sample were chosen; and at Narkūnai 17 striated and one smooth sample were studied.

Sherds were cut with a diamond saw (500 rpg/min) in a vertical position towards the rim or putative side of the rim. The cut surface chosen for analysis was impregnated with epoxy resin, previously heated to 50 °C for 15 minutes. Afterwards the surface was ground and polished with silicone carbide powder (abrasives: 150 to 800 grits) and glued to the microscope slide. Then the sample was cut, leaving a 1-2 mm thick slice, and manually ground with silicone carbide powder (abrasive 800 grits) until it was 30 microns thick.

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3 The Ķivutkalns pottery assemblage is currently being analysed. In this study, pottery from trenches I to VIII, which make up 61.5 % of the excavated area, is presented in detail.

4 The results of the Ķivutkalns pottery petrographic analysis have already been published (Visocka 2020), however in this study the collection has been re-analysed using a different, more developed approach.

Thin section preparation and analysis were carried out at the University of Latvia, Faculty of Geography and Earth Sciences by V. Visocka in 2018.

Wavelength dispersive XRF spectrometry

In order to study and group pottery by its chemical composition, X-ray fluorescence-wavelength dispersive spectrometry (WD-XRF) was used (for a detailed description of the method see Hall 2016). Samples for WD-XRF analysis were chosen randomly from the same sherds which were analysed using ceramic petrography. Overall, 27 samples were analysed using this method (nine samples from each settlement).

We chose a non-destructive approach by irradiating the surface of the selected samples[5]. The *Brucker S8 Tiger* spectrometer with sample holder size of surface irradiation of 5 mm was used. Oxide full analysis in a helium atmosphere was carried out. For each sample three measurements were taken, then the average value and standard error (σ) were calculated. The 14 most common elements in the samples are SiO_2, Al_2O_3, Fe_2O_3, K_2O, P_2O_5, MgO, MnO, CaO, Na_2O, Cl, TiO, BaO, ZnO and SO_3; these were analysed using agglomerative hierarchical clusters (Appendix 3).

The WD-XRF was performed by V. Visocka at the University of Latvia, Faculty of Chemistry, under the supervision of chemist Anna Trubača-Boginska in 2018. Data analysis using agglomerative hierarchical clusters from average values of element concentration in the samples was carried out by data analyst Aigars Mustafājevs.

Results

Clay deposits in the surroundings of the settlements

On-site pottery production at Asva and Ķivutkalns is indicated by irregular clay lumps with granitic rock tempering and with traces of finger impressions and kneading (Sperling 2014, 193; LNVM VI 120: 359; see Figure 3: 1-2). Thus, nearby clay deposits were used. However, more detailed research is needed to clarify this[6]. Here we present only preliminary data from the larger study concerning the use of possible nearby clay sources in these settlements.

Six of the Quaternary clay deposits in Estonia are suitable for pottery production (Raukas and Kajak 1997; Sperling 2014, 194). One of these clay deposits is located in Saaremaa, around 10 km from Asva (Raukas and Kajak 1997; Sperling 2014, 194). As the clay from this deposit is muddy, rich in quartz sand and carbonaceous, it is very suitable for pottery making and therefore might have been used by the Asva potters (Raukas and Kajak 1997; Sperling 2014, 194). Asva itself was established on a moraine, where thick moraine clay layers are common. It is also possible that glacio-lacustrine clay deposits are situated nearby, however, more detailed survey is needed to prove this. Notably, occasional limestone grains and chalk-like impurities[7] have been distinguished in some of the Asva sherds (Figure 3:3-4). Such carbonate concretions often occur naturally in clay deposits, mostly in the upper layer of the clay bed at depths of 0.5-1.5 m (Kuršs and Stinkule 1972, 60, 64). This could mean that potters used the upper areas of the clay deposit (maybe even started to collect from a new clay bed?) for making these vessels; however, more detailed study is necessary.

In the lower reaches of river Daugava, large or even medium-sized high-quality Quaternary clay deposits are not common, as this region mainly consists of Devonian rock outcrops (Kuršs and Stinkule 1972, figs 7, 17). Notably, there is a large Devonian clay

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5 This was decided so that the data could be compared with samples where it was not possible to use a destructive approach (i.e. preparing powder from the sherd), such as pottery from graves and unique pieces.

6 Around 30 clay samples have been collected during surveys in the surroundings of Asva, Ķivutkalns and Narkūnai from 2018 to 2020 and are now being analysed.

7 These impurities were identified by geologist Vija Hodireva at the University of Latvia, Faculty of Geography and Earth Sciences in 2019.

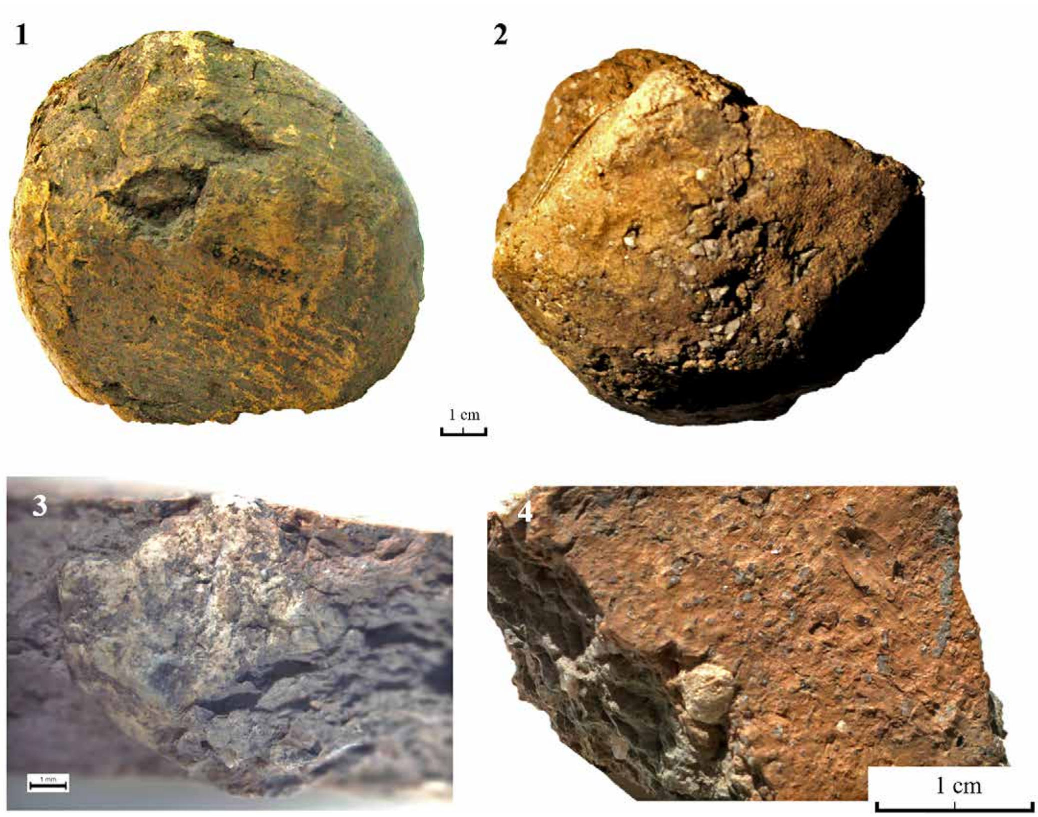

Figure 3. Irregular clay lumps/raw materials found in Asva (1, TÜ AI 3799:22) and Ķivutkalns (2, LNVM VI 120: 359), and limestone and carbonate concretions in Asva pottery paste (3-4, from excavations in 2019 and 2020; photos by U. Sperling (1) and V. Visocka (2-4)).

deposit on Dole island[8] with semi-plastic and carbonaceous clay (Kuršs and Stinkule 1972, 41-43). Although using clay from this deposit would have been very convenient for the Ķivutkalns potters, it is not definitive that this source was used. During survey, several small clay beds were distinguished on both banks of the river Daugava, which could be another potential source for the Ķivutkalns potters[9].

The clay sources around Narkūnai have previously been identified by stereoscopic analysis; however, no further tests on clay quality were carried out. During geological surveys, four large clay deposits were distinguished within a radius of 3 km around Narkūnai (Guobytė 2011; Podėnas *et al.* 2016, 213). Furthermore, Narkūnai itself was established on a clay deposit (Guobytė 2011; Podėnas *et al.* 2016, 213). The surrounding soil of the promontory is clayey as well. Therefore, this material was easily accessible for the community, a trait shared by most LBA fortified settlements in north-east Lithuania (Troskosky *et al*. 2018, 69-70).

Clay matrix of the ceramic vessels

Results of WD-XRF spectroscopy

The major elemental composition data obtained from WD-XRF spectrometry was displayed in a dendrogram using the Ward Linkage method (Figure 4). Overall, three groups with nine subgroups were distinguished.

The first group consists of eight samples from all three settlements. Samples in subgroups correspond with each other. It is notable that there is no subgroup in which samples from all three settlements are linked together. The samples in subgroup 1.1. are more similar to each other than to the rest of the subgroups within this clade.

8 The location of this clay deposit has not been described in detail and is currently unknown to the authors.

9 Survey by Vanda Visocka and Mārcis Kalniņš in 2020; clay samples are being analysed.

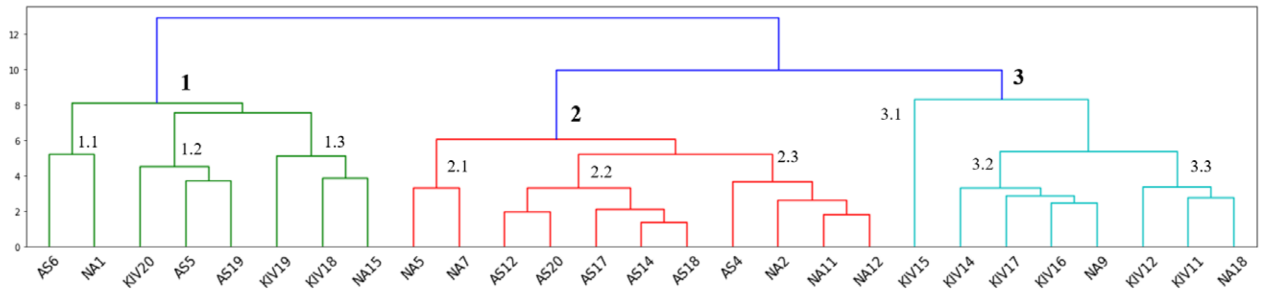

Figure 4. Dendrogram created from WD XRF data (figure: A. Mustafājevs).

The second group is the largest and consists of 11 samples. Notably, this group only includes Asva and Narkūnai samples. Subgroup 2.1. consists of Narkūnai samples, which are more similar to each other than to the rest of the subgroups within this clade. In turn, subgroup 2.2. consists only of Asva samples. It should be noted that samples AS14 and AS18 are the most similar to each other out of all chunks in the dendrogram.

The third group consists of eight samples and includes only Ķivutkalns and Narkūnai material. Sample KIV15 within the third group is simplicifolious and therefore has been completely separated from the other subgroups.

In most cases there are no clear groups characteristic for the different regions. Therefore, clay types similar in their chemical composition were used, resulting in quite random grouping – with the exception of subgroups 2.1. (only Narkūnai samples) and 2.2. (only Asva samples). Notably, these samples do not differ from the rest either morphologically or in their tempering.

Results of visual and petrographic analysis

Visual and petrographic observations show that mainly granitic rock grains (determined by feldspar, quartz and mica minerals in the clay mass) of various sizes were used as a tempering material in all three settlements. The sizes of the temper added to coarse ware vessels vary, with maximum grain size starting from 1 mm and reaching 8 mm. However, in the case of Asva fine pottery, quartz sand and fine crushed granitic rock has been added as tempering material (Sperling 2014, 195). Seemingly no tempering material was added to some miniature and small vessels (2-6 cm in diameter).

Thin section analysis of one sample (KIV8) distinguished a possible grog grain. However, this is not definitive, and thus this aspect will not be taken into account in fabric grouping. Based on clay properties and tempering, as revealed by thin section analysis, 11 clay fabric qualities can be distinguished (Appendix 4).

The data (Figure 5:1) show that each settlement's potters had their own individual preferences regarding preparation of the clay paste, i.e. ware types do not correlate with each other. Notably, in terms of clay paste variations Asva is more similar to Narkūnai than Ķivutkalns. The Asva and Narkūnai pots were mostly made of finer-tempered paste with smaller and less numerous impurities than the Ķivutkalns ceramics. Asva and Narkūnai also have more clay paste recipe variations than Ķivutkalns. Overall, the groups produced from WD-XRF elemental data do not correlate with the pottery ware groups, with the exception of one sample from Ķivutkalns (KIV15) which differed from the others by some of the clay matrix qualities and chemical properties.

Building the vessels

Vessels were hand-made using a coiling method. Potters first created a separate round-bottomed base or one-piece base with sides slightly pulled upwards. Afterwards, clay coils were placed on top of each other and pressed together (Dumpe 2003, 114; Sperling 2014, 199; Vasks 1994, 49). Two types of coiling techniques could be distinguished in this study, U and N. Using the U technique, both sides of the clay band are smoothed downwards, creating an upside down or upright U-shaped distortion in the coils (Dumpe 2003, 115; Neumannová *et al.*

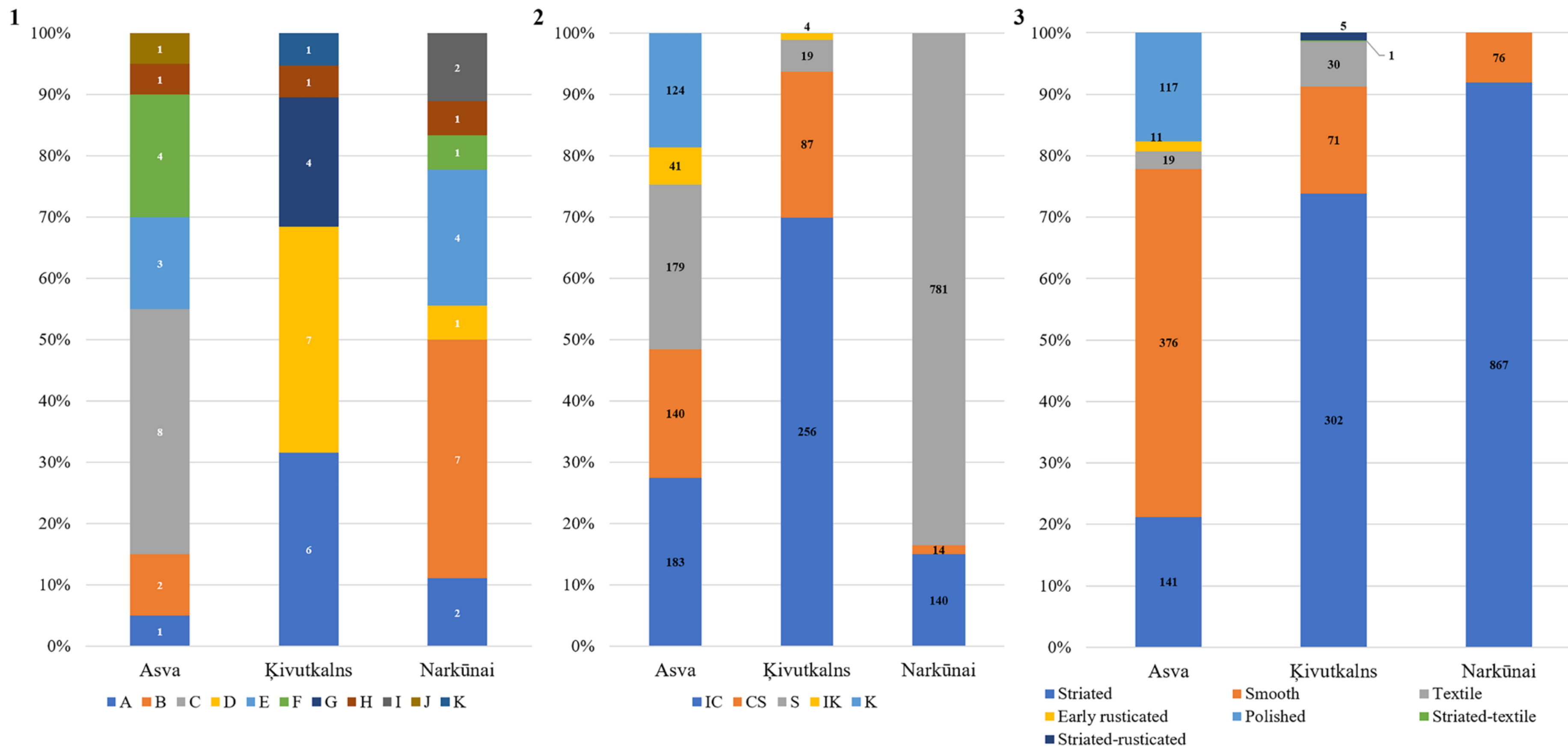

Figure 5. Frequency of ware types (1), rim shapes (2) and surface treatments (3) in the assemblages. For abbreviations of rim shapes, see Figure 2.

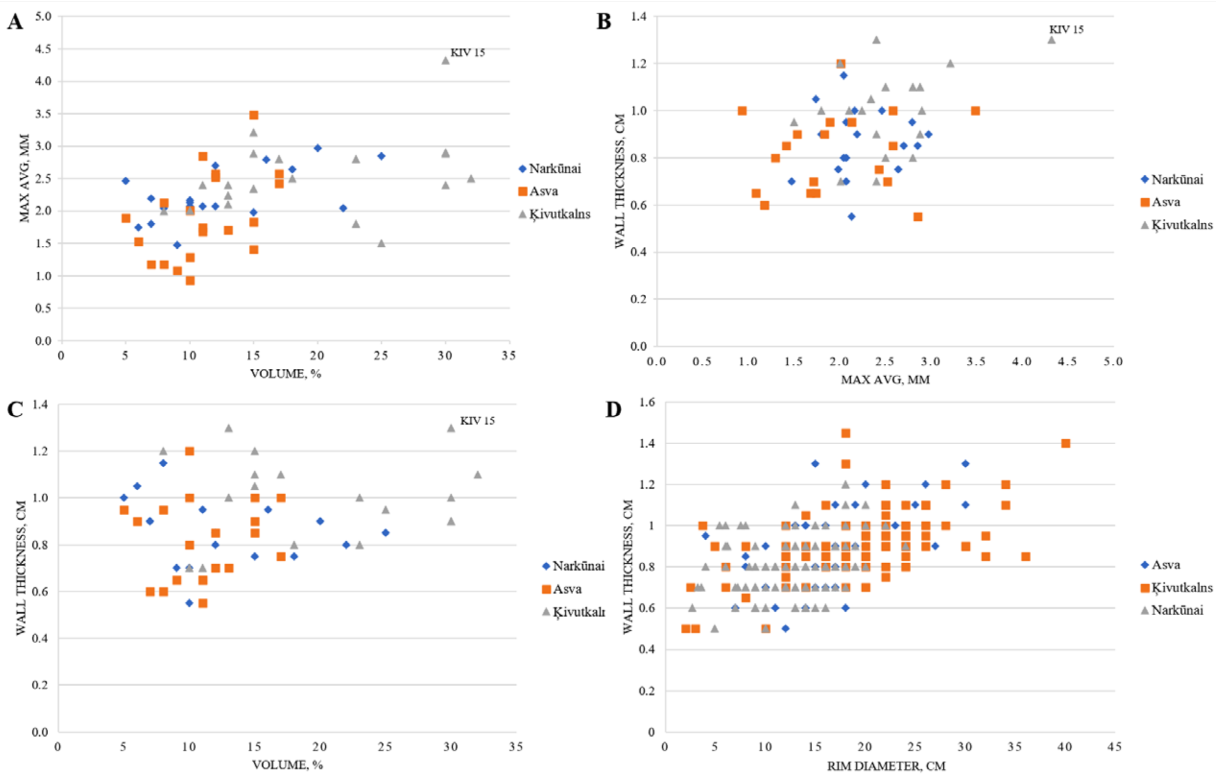

Figure 6. Scatterplots of different vessel qualities. A: tempering volume to maximum average grain size; B-C: tempering qualities to wall thickness; D: vessels size to wall thickness.

2017, 174). In turn, in the N technique coils were smoothed in opposite directions, creating a slanting distortion (Dumpe 2003, 116; Neumannová *et al.* 2017, 174). According to Baiba Dumpe, the N technique makes pottery production faster than the U technique (Dumpe 2003, 116). The dominant coiling technique in all three settlements is N. The U technique has been identified only in Asva and Ķivutkalns. Vessels were built mainly from smoothened clay coils 3-8 cm wide; however, in Ķivutkalns they can reach 10 cm (Visocka 2017a, 61). Notably, miniature vessels are usually made from one clay lump, without coiling (Vasks 1994, 53).

The wall thickness of the vessels varies from 0.4 to 1.6 cm and their rim diameter from 2 to 40 cm. In all three settlements the maximum wall thickness overall correlates with vessel size, tempering maximum average grain size and volume of the added temper (Figure 6). Thus, wall thickness depends on the size and tempering properties, or the other way around – vessel size and temper depend on the intended wall thickness. The exceptions are miniature and small vessels (up to 10 cm in rim diameter), where there is no clear correlation between vessel size and wall thickness (0.5-1.0 cm). Ķivutkalns pottery mostly falls outside the overall production tendencies, having a much coarser clay paste and larger vessels. Especially interesting is sample KIV 15 (Figure 6: A, B, C) which stands out most in terms of temper (volume and grain size). This result also correlates with WD-XRF spectrometry results, where this sample is similar yet different from the third group subgroups. However, it follows the general trends of ware D.

In each settlement, potters had their own preferences regarding rim profile shapes (Figure 5:2). At Asva there is much more diversity in vessel shapes than elsewhere; notably, all of the profile forms distinguished are equally common, except for IK. Not counting the K shape, there are additional shapes which are not found in either Ķivutkalns or Narkūnai, notably category B of fine ware bowls, where the most common ones are those with an S-profiled rim (B II; for details see Sperling 2014, 188-90). However, Ķivutkalns potters preferred barrel-shaped vessels, those with slightly curved mouth are less frequent. Four instances with IK shape have also been found. In turn, Narkūnai potters had the least variation regarding shape; they preferred strongly curved vessels with everted rim, while barrel-shaped pots were far less common.

Overall, each settlement had their own preferences of vessel building techniques and morphology. The only similarities between settlements regarding building are the size and wall thickness ratios of the vessels. However, these parameters are more likely to be dependent on the function of the vessels, not on aesthetic and technological preferences. The Narkūnai potters are more consistent compared to Asva and Ķivutkalns, as they prefer to use only the N technique of vessel building and do not adopt other non-local shapes, such as IK.

Exterior

The exterior of the vessels, such as surface treatment, ornamentation and some plastic elements, is one of the main components in evaluating aesthetic tendencies and possible influences between styles from different regions.

Surface treatment

Overall, seven types of surface treatment were distinguished: striated, smooth, polished, textile, early rusticated[10], striated-textile and striated-early rusticated (Figure 7:1). The proportion of surface treatments in the Ķivutkalns and Narkūnai assemblages is typical of the archaeological culture of Striated Pottery, which is a local vessel exterior type dominating in the territories of Latvia, Lithuania and Belarus (Graudonis 1980, 59). This type of surface treatment is less preferred in Asva, where vessels with smooth surfaces are most common (Figure 5:3). The striations on the pots were made using bundles of sticks or grass in order to make the pottery more resistant to thermal shock (Schiffer *et al.* 1994) and thus more durable. Mostly, the striation of the vessels was irregular, criss-crossed and quite random; the upper part of the rim is often left smooth. Many of the vessels in Ķivutkalns (41.6 %; Vasks 1991, tab. 8) and Narkūnai (59.1 %) have striated interiors. This has been observed in Asva pottery as well (Sperling 2014, 213). In Asva and Ķivutkalns, a small amount of textile-impressed pottery has been found. The textile surface has been created using notched or braided cord which has been wrapped around a stick (Dumpe 2006, 81).

Polished surface treatment is common in pottery from Asva and it is found in small numbers at several sites in the western areas of the east Baltic (such as Kukuliškiai and Paplaka fortified settlements and Kvietiniai open settlement; Vengalis *et al.* 2020b; Visocka 2016a, 30). In the case of Paplaka, the polished sherds could date to the Pre-Roman Iron Age or the beginning of the Roman Iron Age, as the radiocarbon dates from the lower context span 395-104 cal BC (Haferbergs 2018, 84)[11]. However, this type of surface is not found in Ķivutkalns and Narkūnai. Polished pottery has not been found at LBA archaeological sites further inland in south-east Latvia and north-east Lithuania, and thus is not typical in these regions. Until recently, this kind of pottery in Lithuanian multi-period settlements, including Narkūnai, was interpreted to date from the Roman Iron Age (Podėnas *et al.* 2016, 212-13). However, new data from the coastal fortified settlement of Kukuliškiai indicate that it is also present in contexts dating to c. 900-400 cal BC (Vengalis *et al.* 2020b, 32). We need more data to assess whether this is a regional trait of coastal sites or whether polished pottery was also produced in inland settlements. Polished pottery in north-east Lithuanian assemblages lacks charred organic residues for direct dating and is so far absent from sites with short-term occupation records. Mostly bowls and fine ware pottery were made with polished surfaces (Sperling 2014, 209). Notably, the Asva vessels include examples with

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10 Also known as coarse-slipped. Early rusticated vessels differ from late rusticated ones in the texture of the slip: in the former it is grainy with sand or rock additions and dated to the LBA, in the latter it is finer and more vein-like and is typical of the Iron Age.

11 The Paplaka dates (Haferbergs 2018) were recalibrated to 95.4 % probability using the IntCal20 curve (Reimer *et al.* 2020) in OxCal (Bronk Ramsey 2017).

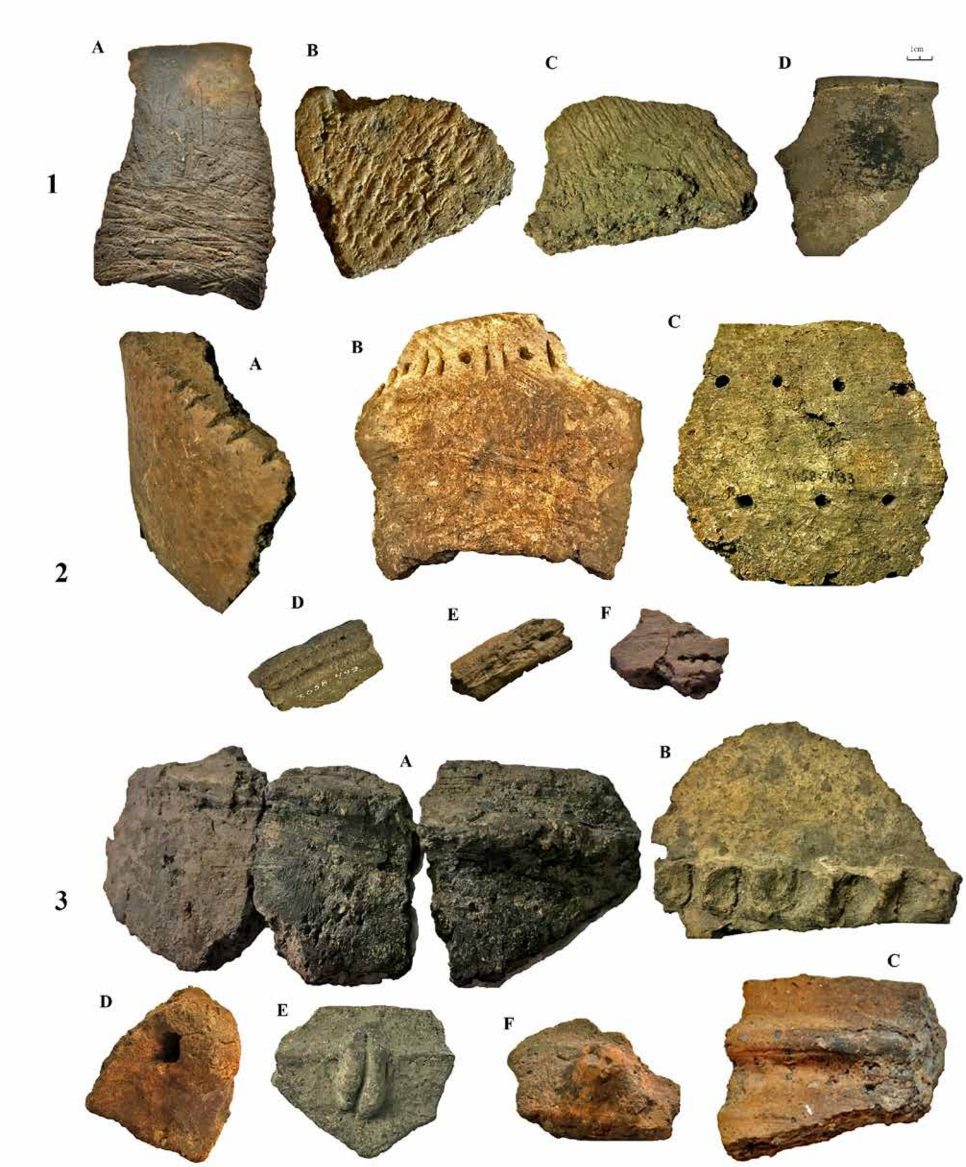

Figure 7. Attributes of vessel exteriors. Row 1: surface treatment. A, striated from Narkūnai (LNM 730, 5 – 1977); B, D, textile and polished from Asva (from excavation in 2019); C, striated-early rusticated from Ķivutkalns (LNVM VI 120). Row 2: ornamentation. A, notches on Asva vessel (TÜ AI 4366:1625); B, dimples and notches from Ķivutkalns; C, dimples from Asva (TÜ AI 3658:433); D-F, cord impressions from Asva (TÜ AI 3658:492) and Ķivutkalns (LNVM VI 120). Row 3: plastic elements. A-C, clay band around vessels from Ķivutkalns (LNVM, VI 120), Asva (TÜ AI 3799:350) and Narkūnai (LNM 1978, 2a, 624); D-E, knobs from Ķivutkalns (LNVM VI 120) and Asva (TÜ AI 3658:313); F, applied oval lens from Ķivutkalns (LNVM VI 120) (Photos: 1A and 3C by V. Podėnas; remainder by V. Visocka).

early rusticated surfaces. A thin clay layer mixed with fine granitic rock or sand was added to the vessel surface (Vasks 1996, 148), perhaps to make the pots more resistant to thermal shock and more waterproof (Schiffer *et al.* 1994; Vasks 2001a, 205).

In Ķivutkalns two subgroups of surface treatments were found, striated-textile and striated-early rusticated. Striated-textile combines the techniques of striation and textile impressions. In turn, striated-early rusticated refers to striated vessels on which a clay layer with rock or sand temper is added (Vasks 1991, 41). Unfortunately, this subgroup is hard to distinguish, as the clay slip needs to have partly fallen off to reveal the striation beneath.

Ornamentation

Regarding ornamentation on the vessels (Figure 7:2), quite different tendencies are seen in each assemblage. Asva has a large number of decorated vessels – c. 75 % of all pots, with various elements and motifs (Sperling 2014, fig. 96). In contrast, in Ķivutkalns ornamented pots make up 0.34 % of the assemblage, the style of decorative elements is much simpler, and motifs are rare (Visocka 2016b, tab. 1). In turn, in Narkūnai ornamentation was an extraordinary practice, as only two fragments were decorated with one line of small pits around the neck of the pot (Podėnas *et al.* 2016, 210).

The most common ornament are dimples. In Asva they make up 80 % of all decorated vessels, in Ķivutkalns 67 % (Sperling 2014, 227; Visocka 2016b, tab. 1). Dimples in these assemblages are usually round or elongated, their diameter varies from 0.4-11 mm. They are made with a stick or stamp-like object, possibly a bone or wooden pin, pressing or "drilling" it into the wet surface of the vessel (Sperling 2014; Visocka 2016b, 82). Fingerprint traces on the inner wall indicate that the inner surface was supported while the dimples were added (Sperling 2014, 227-28). Dimples were mostly pressed in one, sometimes in up to five rows on the shoulder or neck part of the vessel (Sperling 2014, plate 34; Visocka 2016b, 82). In one case the rim was ornamented with dimples (Sperling 2014, 232 plate 35). Notably, dimple ornamentation is less common among the fine ware vessels from Asva.

Another ornamentation found in Asva and Ķivutkalns are cord impressions. In Ķivutkalns this is the second most common ornamentation, making up 18 % of all ornamented sherds (Visocka 2016b, tab. 1). Three fragments had both cord and dimple ornamentation (Visocka 2016b). In Asva, this ornamentation occurs only occasionally. In the case of Asva, the dating of these kinds of vessels is debatable, as the decoration method differs from the rest of the assemblage (Sperling 2014, 230). Cord impressions are made with a cord wrapped around a stick and applied in slanting or horizontal lines (Vasks 1994, 50).

Ornaments made of notches are less common in the Asva and Ķivutkalns assemblages. In Asva coarse ware with notches makes up approximately 5 %, while 21 % of fine ware vessels have this ornamentation (Sperling 2014, 229-30, 233-34). Sometimes notches are used to decorate the rim of the Asva vessels. In Ķivutkalns there is no ornament consisting of just notches, they are always complemented with dimples. Such vessels make up 8 % of all decorated examples (Visocka 2016b, tab. 1). Notches are made with a fingernail or knife-like object.

Asva coarse ware vessels stand out for their finger-pinch ornamentation on the rim or shoulder of the pot. Sometimes this decoration occurs on a clay band wrapped around the vessel (Sperling 2014, 229 plate 34). This ornament makes up 25 % of all decorated sherds (Sperling 2014, 227). Overall, it is not common for settlements in the Daugava basin, but rather in western parts of Latvia (Visocka 2016b, 87). Quite unique among Asva's coarse ware ceramics is a vessel with incised three-row zig-zag lines and dimple ornamentation (Sperling 2014, 231 plate 47).

The fine ware pottery of Asva, where various detailed ornaments and motifs appear on the surface, is the most decorated of all three assemblages. This kind of pottery shows a high quality in both building and ornamentation (for details see Sperling 2014, 233-39).

Plastic elements

The Asva pottery is quite rich in plastic elements, such as handles and knobs, clay bands and oval lenses (Figure 7:3). Overall, elements like handles and knobs are not common on Latvian and Lithuanian LBA pottery. In the Ķivutkalns fortified settlement only one pottery fragment with a small knob has been found (LNVM VI 120: 387).

Two plastic ornament types are distinguished: clay bands wrapped around the vessel and oval applied lenses. Clay bands were found on material from all three settlements (Podėnas *et al.* 2016, pav. 7). As mentioned before, ceramics from Asva are often ornamented with finger-tweaks or dimples. In turn, Ķivutkalns and Narkūnai pots with clay bands either have smooth surfaces or light striation. The clay bands are wrapped around the neck or shoulders of freshly made vessels before firing (Graudonis 1989, 49).

Applied lenses can be considered a rare plastic ornament. Only three sherds from Asva and two from Ķivutkalns have it (Sperling 2014, 214; Visocka 2016b, tab. 1). It is not precisely known how these plastic elements were added to the vessel's surface – while building the vessel or afterwards. Some detached lens fragments from the Krievu kalns fortified settlement in western Latvia (LNVM A13958: 17) indicate that the latter possibility is more likely.

In terms of vessel exterior, Narkūnai seems to be the most "conservative" site, as it has only two surface treatment variations and practically no ornamented vessels, only dimples and one plastic element. In turn, Asva has the full range of ornamentation and plastic elements in its pottery, which is both aesthetic and of high quality. Ķivutkalns shows traces of stylistic interactions between regions, especially because there is a fusion of local and foreign traditions: striated-textile and striated-early rusticated surfaces, alongside some non-local plastic elements, such as applied lenses and knobs.

Discussion

Pottery is a complex informative source due to its technomic (practical-functional) and sociotechnic (style as social gesture) features (Eriksson 2009; 2012). These are integral parts of the socio-cultural system responding to the given economic necessities, constraints (materials, techniques) and choices based on tradition. Asva, Ķivutkalns and Narkūnai pottery assemblages represent people and visitors in three different ecological and economic milieus. Asva was the nearest to the sea. The Tehumardi hoard and the Lülle stone ship setting (Lang 2007, 164; Sperling 2013), both with finds and funerary practices atypical for the eastern Baltic, indicate that this area was actively visited by possible travellers from the western Baltic or Baltic islands such as Gotland. Ķivutkalns occupied a site in the mouth of the Daugava river, an important trade artery to settlements established inland. Following the river to its origins in the Valdai hills, people could have reached areas in the basins of the Baltic, Black and Caspian Seas, opening a large area to long-distance trade. The settlement is also distinguished by two hoards found in its cultural layer with bronze tutuli typical for the Lusatian culture (Graudonis 1989; Urtāns 1977; Vaska 2019). In the vicinity of the Daugava in south-east Latvia and north-east Lithuania, a dense cluster of fortified settlements emerged, whose southern areas were already within the Šventoji river basin. Thus, it was postulated (Podėnas and Čivilytė 2019) that sites like Narkūnai worked as further trading grounds between locals, established in the southern inland open settlements, and northern fortified settlements. The three assemblages share some technological traits of pottery production. In other aspects, coastal and inland practices can be distinguished, and assemblages differentiated based on the intensity of influence from outside the eastern Baltic region, namely from Scandinavia and the Lusatian culture.

Coastal pottery assemblages in the eastern Baltic were more diverse, with a wider range of ornamentations and morphological variety. This was expressed through the appearance of knobs, polished fine ware and semi-biconical profiles, whereas ceramics made in inland settlements are characterised by a more homogenous practice of striated or smooth pottery with semi-coarse and coarse ware and profiled or barrel-shaped forms. Furthermore, Asva and Ķivutkalns, like other coastal assemblages in the region, have yielded low frequencies of early rusticated ware or its subtypes. This is a dominant pottery type for the western and southern Baltic and their presence even in low frequencies in specific eastern Baltic regions[12] is indicative of contacts between these territories. The emergence of striated-early rusticated and striated-textile vessels, where local and non-local surface treatment traditions mix (Vasks 1991, 41), indicates that there was at least some transmission of knowledge and techno-aesthetic influences between communities in different regions. It was previously thought that early rusticated and striated-early rusticated vessels are common only in the eastern and western part of Latvia, such as at the fortified settlements of Brikuļi, Krievu kalns, Padure (Beltes) and Paplaka (Visocka 2017b). However, this type has recently been found in the Vīnakalns and Ķivutkalns pottery assemblages, showing that it occurs along the lower reaches of the river Daugava as well. Moreover, recent reports (Simniškytė-Strimaitienė 2019) also indicate the appearance of this style at the Kupiškis hilltop settlement in north-eastern Lithuania.

12 Especially north of the West Balt Barrow culture and the Neris river.

The situation is different for textile and striated-textile vessels, which occur in small amounts in central and eastern Latvia and in Estonia, such as at Kõivuküla, Asva, Ridala and Iru (Lang 2007; Sperling 2014; Valk *et al.* 2012; Vasks 2001b). Textile pottery from Latvia is very fragmentary and rarely ornamented, in turn textile vessels in Estonia are quite well preserved and ornamented, mainly with dimples (Lang 2007; Sperling 2014). Notably, this type does not occur south and west of the Daugava river, with the exception of the Padure fortified settlement in Courland (Vasks *et al.* 2011). The decrease of ornamentation from the seaside to inland areas is tangible in the pottery assemblages. The most exquisite ornamentation is seen in Asva pottery and decoration was almost non-existent in Narkūnai, where only few samples with dimple ornamentation have been found.

A comparable situation is seen in the vessel profiles. Asva has the most diverse profile shapes and all are roughly equally common. As in other coastal fortified settlements in Estonia (Ridala and Iru), semi-biconical and biconical (IK, K) vessels are present; most likely this shape came from Scandinavia and is due to outside influences either directly from Scandinavia or from continental Europe (Sperling 2014). However, along the lower reaches of the river Daugava and in eastern Latvia, barrel-shaped (IC) vessels are more common (Vasks 1991; Visocka 2017a). West and south of the Daugava there are different tendencies regarding profile shapes, with semi-profiled and profiled (CS, S) shapes being dominant (Vasks 1991; 2011; Vasks *et al.* 2019; Visocka 2017a). The plastic elements of clay bands wrapped around the vessels are a notable feature of settlements in the eastern Baltic. This element could be related to techno-aesthetic influences from Scandinavia and central Europe (i.e. the Lusatian culture), as locals could have attempted creative imitations of semi-biconical and biconical vessels. According to pottery specialist B. Dumpe, semi-biconical and biconical vessels are not harder to build than barrel-shaped and profiled ones; however, potters have to adapt their skills for creating vessels of different shapes[13].

The greatest similarities between our studied sites are seen in tempering material. In all cases, except where quartz sand was used as a temper, crushed granitic rock was added to the clay paste. This is no surprise as this material is the dominant temper in eastern Baltic LBA pottery. Similar size ratios of added grains in each sample indicate that sieving was used to create differently sized tempers. Eleven variations of clay recipes were distinguished. Mostly, semi-coarse and coarse temper was added to the clay paste in various volumes. This is also a common trait of LBA pottery in the east Baltic, therefore the analysed settlements fit into the overall regional tendencies. Fine ware pottery of the kind found at Asva is also quite common in Estonia (Lang 2007; Sperling 2014). Our data indicate that morphologically coarse ware can sometimes be tempered with fine material or the other way around. Thus, possibly the same clay paste was used at the time of production. Notably, the Ķivutkalns assemblage is characterised by coarser clay, as more tempering material was used compared to the Asva and Narkūnai assemblages. Similar tendencies occur in other settlements along the lower reaches of the Daugava, for instance at Dievukalns and Vīnakalns (Visocka 2017a; 2017b). Therefore, this is a regional pattern, which could result from the available kinds of clay in the area.

An overall decline in the morphological variation of pottery is evident when moving from coastal to inland settlements, with assemblages progressively more uniform and modest. Estonian Saaremaa pottery traditions are techno-aesthetically strongly influenced from other regions due to active exchange and communication. Although being likewise an active trade and communication region, fewer traces of Scandinavian or central European influences are recognisable in the pottery of communities settled along the lower Daugava. In these assemblages there are some possible imports, e.g. vessels with knobs and applied lenses. However, vessels in this region have a much coarser clay matrix and less ware variations compared to coastal and inland pottery. The morphologically most uniform pottery is found inland (Narkūnai).

13 B. Dumpe (National History Museum of Latvia), pers. comm.

Conclusions

Ceramic vessels contain much information about socio-cultural values and techno-aesthetic tendencies, as well as culinary practices. Communities established in the three different ecotones studied here produced pottery with varied degrees of stylistic variation in applied surface treatment technologies and ornamentation. However, pottery makers in Asva, Ķivutkalns and Narkūnai expressed similar behaviour up to the point when the vessel exterior was designed; the only exception is the production of fine ware in Asva.

The clay used in pottery production was mostly purified. Only Ķivutkalns vessels were made from coarse clay with varied impurities of different sizes, perhaps dependent on the clay source used. A similar situation is seen in other settlements established along the lower Daugava, making this a micro-regional trait. In terms of their chemical composition, samples were grouped randomly, indicating that chemically similar clay had been used throughout. There are two subgroups, respectively containing only Asva or Narkūnai vessels. A single sample from Ķivutkalns differs chemically and in temper. Two types of tempering material were distinguished – sand (in Asva) and crushed granitic rock. Overall, 11 ware types were identified which fit with the general tempering tendencies of eastern Baltic pottery. The fine ware from Asva is characteristic of other Estonian coastal settlement pottery, such as that from Iru and Ridala.

The assemblages from the fortified settlements studied here show different influences and individual preferences. Coastal pottery was more diverse than that found inland, with more outside influences apparent in the variety of vessel morphology, surface treatment and ornamentation. This diversity declines further inland, where fewer decorative elements and different morphological preferences are noted, representing a more uniform tradition. Plastic ornaments, such as knobs, clay bands and applied lenses, as well as polished fine ware and biconical shapes are most likely inspired from Scandinavia and central Europe. Thus, the clearest techno-aesthetic influences between regions are identified rather in the vessels' visual appearance than in the ways they were produced.

Concerning how such influences were spread, we consider personal mobility and transfer of ideas as likely mechanisms. None of the pottery types in the three sites were made for transportation, therefore we rule out the possibility of trade. Based on comparanda from burial sites and on metallurgical assemblages from settlements, there is a possibility of transregional communication enacted by visitors, whose behaviour was learnt or imitated by the local inhabitants of the eastern Baltic. Varying quantities of different stylistic elements are found in different regions. Most of the plastic elements occur in coastal areas, whereas early rusticated wares permeate territories connected to the Baltic Sea via the Daugava. The pottery traditions in other inland areas along other river systems follow more conservative traditions and could indicate more restricted communication between these inland communities, who were less well incorporated into the interregional communication networks.

Acknowledgments

The authors would like to thank the State Culture Capital Foundation (SCCF) of Latvia for financing materials for petrographic analysis (project no. 2018-3KMA001-P), the National History Museum of Latvia, the National Museum of Lithuania and the University of Tallinn Institute of History, Archaeology and Art History for allowing us to use pottery assemblages for analysis, as well as the geologist Vija Hodireva, the pottery specialist Baiba Dumpe, the data analyst Aigars Mustafājevs and the chemist Anna Trubača-Boginska for consultations and help with analysis, the archaeologist Mārcis Kalniņš for help with survey, as well as two reviewers of our article for their suggestions.

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Appendix 1: Complete list of the fortified settlements in the eastern Baltic mapped in Figure 1

These sites all have associated ^{14}C dates or were dated based on typological studies of Bronze Age metal, clay and bone artefacts (Graudonis 1967; 1974; 1989; Jegoreichenko 2006; Lang 2007; Luchtanas 1992; Podėnas 2020; Šmigelskas 2018; Vasks *et al.* 2019; with our additions and modifications). Chronologically more widely dated artefacts, such as stone axes or various pottery styles, were not considered sufficient for inclusion in the map, as there is a risk of mixing Late Bronze Age and Early Iron Age processes by including these finds. There is significantly more knowledge on Kaliningrad fortified settlements established already in the Late Bronze Age, however the results of an ongoing project are yet to be published[14].

- Estonia: Asva, Iru, Kaali, Kõivuküla, Narva, Ridala;
- Latvia: Asote, Baltkāji, Brikuļi, Dievukalns, Dignāja, Jersika, Klaņģukalns, Klosterkalns, Krievu kalns, Ķenteskalns, Ķivutkalns, Mūkukalns, Madalāni, Padure, Paplaka, Rušenica, Sārumkalns, Smārdes Milzukalns, Stupeļu kalns, Tērvete, Vīnakalns;
- Lithuania: Antilgė, Dūkšteliai I, Garniai I, Juodonys, Kereliai, Kukuliškiai, Kupiškis, Kurmaičiai, Luokesai I, Mineikiškės, Moškėnai, Narkūnai, Nemenčinė, Nevieriškė, Pakačinė, Petrešiūnai, Sokiškiai, Spitrėnai, Velikuškės I, Vilnius (Gedimino kalnas), Vorėnai, Vosgėliai, Žagarė I;
- North-east Poland: Szurpiły, Tarławki, Zubronajcie;
- Russia: Osyno;
- Belarus: Bancerovsčina, Dvorisče, Gatoviči, Gorany, Gorodisče, Kasčelici, Labensčina, Ratjunki, Tarilovo, Zanoroč, Zazony.

14 Timo Ibsen (ZBSA Schleswig), pers. comm.

Appendix 2. Results of the petrographic analysis

CODE	SAMPLE INFORMATION			CLAY								TEMPER					WARE
	Inventory No.	Surface treatment	Wall thickness, cm	Coarseness	Sortedness	Silt	Fine sand	Sand	Mica	Iron oxides	Carbonate concretions	Type	Volume, %	Max. grain size, mm	Max.avg. Size, mm	Homogenity	
ASVA																	
AS1	TÜ, AI 3658: 693	Textile	0.85	fine	sorted	-	-	-	-	-	n	granite	12	3.6	2.58	+	**F**
AS2	TÜ, AI 3994: 951	Striated	0.75	fine	sorted	-	-	-	-	-	n	granite	17	4.05	2.43	+	**F**
AS3	TÜ, AI 3307: 259	Polished	0.6	fine	sorted	*	+	*	*	*	n	granite	8	1.5	1.17	+	**C**
AS4	TÜ, AI 4366: 1535	Smooth	0.65	fine	medium	*	*	*	-	-	n	granite	11	2.55	1.74	+	**D**
AS5	TÜ, AI 3994: 357	Striated	1	fine	medium	-	*	*	-	-	n	granite	17	3.75	2.58	+	**D**
AS6	TÜ, AI 3799: 387	Striated	0.95	medium	unsorted	-	-	*	-	*	*	granite	5	4.05	1.89	+/-	**B**
AS7	TÜ, AI 3658: 699	Striated	0.9	fine	sorted	-	-	*	*	*	n	granite	6	2.1	1.53	+/-	**C**
AS8	TÜ, AI 7065: 2663	Polished	0.6	fine	sorted	-	*	*	*	+	n	granite	7	1.65	1.17	+	**C**
AS9	TÜ, AI 3994: 403	Polished	0.85	fine	sorted	-	*	*	*	*	n	granite	15	1.95	1.41	+	**C**
AS10	TÜ, AI 4366: 1538	Smooth	0.7	fine	sorted	-	-	-	-	-	n	granite	12	6.6	2.52	+	**F**
AS11	TÜ, AI 4366: 1618	Polished	0.8	fine	sorted	-	-	*	*	*	n	granite	10	2.25	1.29	+	**C**
AS12	TÜ, AI 7065: 2476	Smooth	0.9	fine	sorted	-	*	*	*	*	n	granite	15	2.4	1.83	+	**C**
AS13	TÜ, AI 3799: 421	Smooth	0.95	medium	unsorted	-	*	*	-	*	n	granite	8	3.6	2.13	+/-	**B**
AS14	TÜ, AI 7065: 2749	Striated	1	fine	sorted	*	*	*	*	*	n	granite	10	1.5	0.93	+/-	**C**
AS15	TÜ, AI 3658: 687	Polished	0.55	fine	sorted	-	-	-	-	-	n	granite	11	3.75	2.85	+	**F**
AS16	TÜ, AI 3994: 1470	Smooth	0.7	fine	sorted	-	+	*	*	*	n	granite	13	2.1	1.71	+/-	**C**
AS17	TÜ, AI 3658: 561	Striated-textile	1.2	fine	medium	*	-	*	-	-	n	granite	10	2.85	2.01	+	**D**
AS18	TÜ, AI 4366: 308	Polished	0.65	coarse	unsorted	+	+	+	-	-	n	granite	11	2.55	1.68	*	**H**
AS19	TÜ, AI 7065: 2876	Striated	1	coarse	unsorted	*	+	+	*	*	n	granite	15	5.1	3.48	+/-	**A**
AS20	TÜ, AI 4012: 342	Polished	0.65	fine	sorted	-	*	+	*	+	n	sand	9	1.5	1.08	+	**J**
ĶIVUTKALNS																	
KIV1	LNVM, VI 120	Striated	1.1	medium	sorted	+	*	-	-	-	n	granite	32	5	2.5	+	**E**
KIV2	LNVM, VI 120	Striated	1.1	coarse	unsorted	+	*	+	*	-	n	granite	17	3.8	2.8	*	**G**
KIV3	LNVM, VI 120	Striated	0.95	coarse	unsorted	+	*	+	*	-	n	granite	25	2	1.5	*	**G**
KIV4	LNVM, VI 120	Striated	0.8	medium	unsorted	+	+	+	*	+	n	granite	23	3.5	2.8	+/-	**A**
KIV5	LNVM, VI 120	Striated	1	medium	sorted	+	*	-	-	-	n	granite	23	3	1.8	+	**E**
KIV6	LNVM, VI 120	Striated	0.8	medium	medium	+	+	+	*	-	n	granite	18	3	2.5	+/-	**A**
KIV7	LNVM, VI 120	Textile	1	fine	sorted	-	-	*	+	*	n	granite	30	5	2.9	+	**K**
KIV8	LNVM, VI 120	Textile	1.3	coarse	unsorted	+	*	+	*	+	n	granite	13	2.9	2.4	*	**G**
KIV9	LNVM, VI 120	Smooth	0.7	coarse	medium	+	+	+	*	+	n	granite	11	3.9	2.4	+/-	**A**
KIV10	LNVM, VI 120	Smooth	1	coarse	medium	-	+	+	*	-	n	granite	13	4.1	2.1	+/-	**A**
KIV11	LNVM, VI 120	Smooth	1	medium	unsorted	-	+	+	*	-	n	granite	13	2.79	2.24	+/-	**A**
KIV12	LNVM, VI 120	Striated	1.2	coarse	unsorted	+	+	+	-	-	n	granite	8	3.15	2	*	**H**
KIV14	LNVM, VI 120	Striated	1.05	medium	sorted	+	*	-	-	-	n	granite	15	3.3	2.34	+	**E**
KIV15	LNVM, VI 120	Striated	1.3	medium	sorted	+	*	-	-	-	n	granite	30	5.85	4.32	+	**E**
KIV16	LNVM, VI 120	Smooth	0.7	coarse	unsorted	+	*	+	*	-	*	granite	10	3.9	2.01	*	**G**
KIV17	LNVM, VI 120	Striated	0.9	medium	sorted	+	*	-	-	-	n	granite	30	3.75	2.88	+	**E**

CODE	SAMPLE INFORMATION			CLAY								TEMPER					WARE
	Inventory No.	Surface treatment	Wall thickness, cm	Coarseness	Sortedness	Silt	Fine sand	Sand	Mica	Iron oxides	Carbonate concretions	Type	Volume, %	Max. grain size, mm	Max.avg. Size, mm	Homogenity	
KIV18	LNVM, VI 120	Striated-rusticated	0.9	medium	sorted	+	*	-	-	-	n	granite	30	6	2.4	+	**E**
KIV19	LNVM, VI 120	Textile	1.2	medium	unsorted	+	+	+	*	-	n	granite	15	4.8	3.21	+/-	**A**
KIV20	LNVM, VI 120	Smooth	1.1	medium	sorted	+	*	-	-	-	n	granite	15	4.2	2.88	+	**E**
NARKŪNAI																	
NA1	LNM, 1977, 2, 233	Striated	0.75	fine	medium	*	*	*	-	-	n	granite	18	3.75	2.64	+	**D**
NA2	LNM, 1978, 2b, 165	Striated	0.9	medium	unsorted	*	-	*	-	*	n	granite	7	3.6	2.19	+/-	**B**
NA3	LNM, 1978, 2b, 589	Striated	0.95	coarse	unsorted	+	+	-	*	-	n	granite	11	3.75	2.07	+/-	**A**
NA4	LNM, 1977, 3, 2 obj.	Striated	0.7	fine	unsorted	+	-	*	*	*	n	granite	10	3.9	2.07	+/-	**I**
NA5	LNM, 1978, 518	Striated	0.9	medium	unsorted	-	*	*	-	*	n	granite	7	3	1.8	+/-	**B**
NA6	LNM, 1978, 2g, 199	Striated	0.85	fine	medium	-	*	*	-	-	n	granite	12	3.3	2.7	+	**D**
NA7	LNM, 1978, 6, 184	Striated	1.05	medium	unsorted	-	*	*	-	*	n	granite	6	2.55	1.74	+/-	**B**
NA8	LNM, 1978, 2y, 198	Striated	1.15	medium	unsorted	-	-	*	-	*	n	granite	8	3.6	2.04	+/-	**B**
NA9	LNM, 1978, 6, 459	Striated	0.7	coarse	unsorted	+	+	+	-	-	n	granite	9	2.1	1.47	*	**H**
NA10	LNM, 1978, 2b, 588	Striated	1	fine	medium	-	*	*	-	-	n	granite	10	4.5	2.16	+	**D**
NA11	LNM, 1978, 2b, 384	Striated	1	medium	unsorted	*	*	*	-	*	n	granite	5	3.45	2.46	+/-	**B**
NA12	LNM, 1978, 630	Striated	0.8	medium	unsorted	*	-	*	-	*	n	granite	12	4.35	2.07	+/-	**B**
NA13	LNM, 1978, 2b, 581	Striated	0.75	fine	sorted	-	-	-	-	-	n	granite	15	3.3	1.98	+	**F**
NA14	LNM, 1978, 2b, 568	Striated	0.85	medium	sorted	+	*	-	-	-	n	granite	25	3.3	2.85	+	**E**
NA15	LNM, 1978, 2b, 164	Smooth	0.55	fine	unsorted	+	-	*	*	+	n	granite	10	3.9	2.13	+/-	**I**
NA16	LNM, 1978, 641	Striated	0.9	fine	medium	_	*	*	-	-	n	granite	20	3.9	2.97	+	**D**
NA17	LNM, 1978, 549	Striated	0.8	medium	unsorted	_	+	*	*	*	n	granite	22	2.7	2.04	+/-	**A**
NA18	LNM, 1978, 2a, 646	Striated	0.95	medium	unsorted	*	+	*	-	*	n	granite	16	3.75	2.79	+/-	**B**

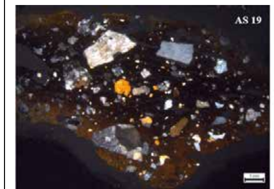
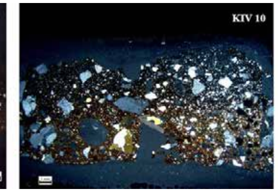
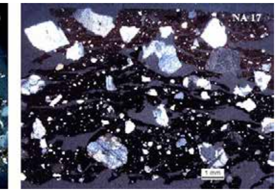
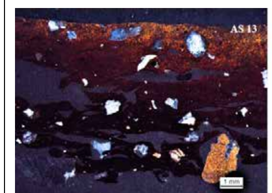
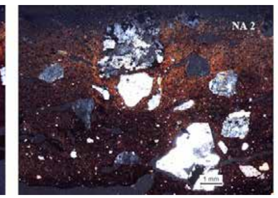
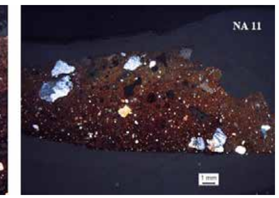
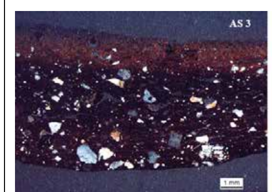
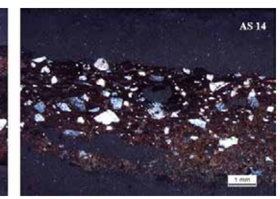
Clay: + rich; * common; - sparse**;** n none; **Homogenity:** + well, +/- medium, * not homogenous

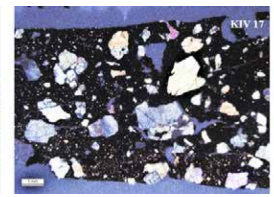
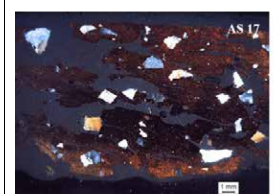
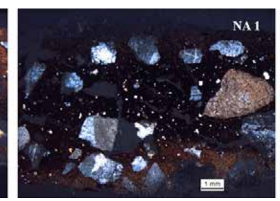
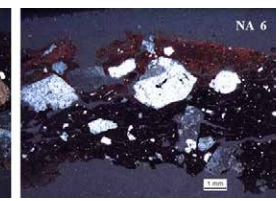
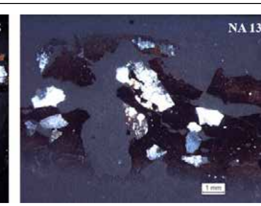
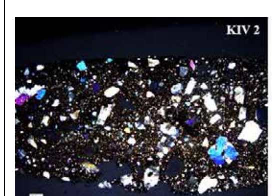
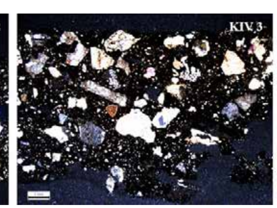
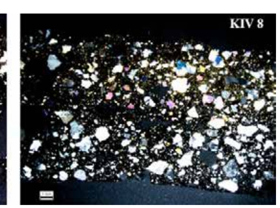
Appendix 3. Results of the WD-XRF Spectrometry

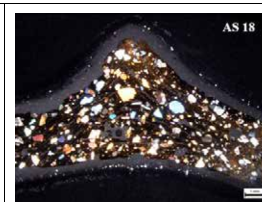
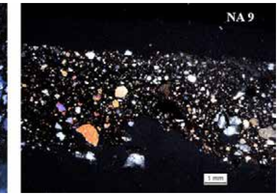
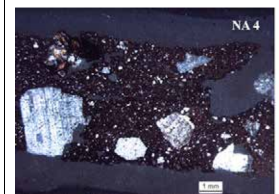
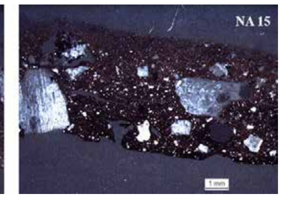
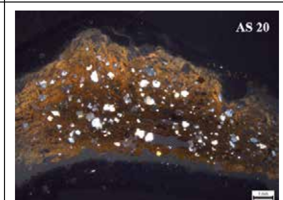
Code	MOST COMMON ELEMENTS, conc., %. NORMALISED							
	SiO2	Al2O3	Fe2O3	K2O	P2O5	MgO	MnO	CaO
AS4	56.39±1.7	18.08±2.2	8.15±2.2	5.3±0.94	1.22±1.35	3.56±1.1	0	3.21±0.9
AS5	37.7±18.53	13.45±6.39	13.56±7.7	6.28±1.4	11.76±13	3.93±1.21	0.06±0.33	9.66±6.41
AS6	42.16±4.15	11.54±1.1	10.14±1	4.48±1.52	9.02±1.94	4.45±0.8	0.07±0.21	13.91±1.9
AS12	48.35±8.2	13.65±4.9	9.31±3.8	4.7±0.62	5.27±3.7	3.26±0.92	0.06±0.17	12.6±5.5
AS14	48.36±7.8	14.38±0.85	10.59±4.4	5.84±0.7	6.45±4.25	3.21±0.85	0.04±0.2	8.19±1.9
AS17	50.23±6.14	12.45±0.5	10.75±0.81	5.99±1.3	6.12±2.5	3.42±1.2	0.06±0.16	7.92±0.74
AS18	49.9±5.2	15.01±4.3	11.57±4.5	5.47±1.54	3.97±0.4	3.34±1.4	0	7.54±4.6
AS19	40.26±33.1	13.48±11.5	14.35±11	4.34±2.01	8.05±6.9	3.16±1.8	0.03±0.18	12.5±29.8
AS20	51.55±5.05	16.07±2.84	9.15±1.81	4.36±1.1	1.17±1.45	3.38±0.91	0.05±0.3	11.13±5.92
KIV11	53.89±13.1	15.96±5.5	10.53±5	4.2±2.1	7.7±6	2.17±0.4	0.16±0.45	2.78±2.15
KIV12	63.45±10	13.91±2.07	4.6±1.73	4.5±0.52	4.72±3.6	2.34±0.64	0.09±0.3	4.21±3.2
KIV14	57.11±0.9	15.77±3	7.73±6.5	5.13±1.24	4.17±1.94	2.17±0.42	0.18±0.2	3.04±8.4
KIV15	58.61±6.94	17.75±7.1	4.53±2.2	3.05±1.5	2.8±1.32	1.19±0.6	0.02±0.11	7.07±0.94
KIV16	65.63±1.3	13.84±1.81	6.8±0.9	3.57±0.5	2.95±1.8	1.92±0.4	0.29±0.1	2.53±1
KIV17	61.89±6.72	13.38±2.6	8.27±5.1	4.13±0.7	3.17±1.75	1.85±0.31	0.12±0	4.5±1.5
KIV18	51.53±2.7	11.37±2.04	5.34±0.6	4.87±1.13	13.52±1.22	2.12±0.3	0.31±0.13	8.69±0.8
KIV19	51.35±24.8	12.21±4.32	6.48±5.1	5.3±1.9	8.14±8	2.53±1.13	0.46±0.42	9.94±14.6
KIV20	52.51±3.23	13.78±1.94	8.18±2.3	4.75±1.1	8.59±3.11	2.56±0.8	0.04±0.24	6.63±3.31
NA1	34.51±16.65	10.55±4.32	11.85±5.45	6.6±1.9	8.7±4.43	4.01±1	0.23±0.71	19.7±13.14
NA2	55.6±3.7	16.73±0.7	10.55±0.76	6.71±0.15	1.32±3.63	3.16±0.4	0	3.18±0.85
NA5	49.57±6.41	15.48±2.82	12.01±1.85	5.8±0.74	5.13±3.72	2.94±0.5	0.46±0.22	5.98±2.94
NA7	55.08±7.6	18.11±2.35	10.51±0.3	5.47±0.7	2.76±4.25	2.65±0.25	0.26±0.32	2.84±2.15
NA9	66.2±3.34	11.12±9.6	6.52±4	4.44±0.75	3.31±3	2.13±0.2	0.15±0.3	3.43±2.53
NA11	56.73±9.5	15.8±1.83	9.51±5	5.21±1.3	1.6±1.24	3.07±0.74	0.08±0.22	5.01±2.7
NA12	55.49±2.72	16.04±1.33	9.52±3.94	5.86±1.42	2.98±2.22	2.99±0.85	0	3.92±1.75
NA15	38.52±13.1	12.39±0.53	11.82±8.75	4.4±1.1	14.47±5.72	2.79±1.9	0.28±0.24	12.76±4.6
NA18	53.91±6	15.62±1.8	7.81±1.01	5.75±1.62	5.39±6.73	2.69±0.8	0.05±0.28	6.29±1.63

MOST COMMON ELEMENTS, conc., %. NORMALISED						Group
Na2O	Cl	TiO	BaO	ZnO	SO3	
2.42±0.41	0.13±0.4	0.86±0.05	0.23±0.08	0.08±0.02	0.25±0.7	**2.3**
0.84±2.32	0.18±0.53	0.74±0.12	0.38±0.34	0.15±0.08	0.67±0.32	**1.2**
1.2±0.1	0.26±0.8	0.71±0.34	0.25±0.1	0.1±0.02	1.31±0.21	**1.1**
0.81±2.22	0.05±0.3	0.81±0.55	0.23±0.1	0.1±0.11	0.12±0.64	**2.2**
0.46±2.5	0.07±0.4	0.86±0.5	0.18±0.2	0.1±0.06	0.33±0.92	**2.2**
0.83±2.4	0.08±0.44	0.82±0.2	0.21±0.11	0.06±0.02	0.44±1.3	**2.2**
0.51±2.8	0.05±0.3	0.88±0.3	0.25±0.4	0.11±0.14	0.34±1	**2.2**
0.71±2.03	0	0.6±1.7	0.31±0.2	0.19±0.4	0.49±1.64	**1.2**
0.47±2.6	0.1±0.57	0.86±0.16	0.24±0.2	0.11±0.02	0.25±0.74	**2.2**
0.92±0.33	0.03±0.18	0.86±0.5	0.18±0.11	0.05±0.03	0.23±1.3	**3.3**
0.5±1.44	0.07±0.4	0.71+/0.14	0.09±0.3	0.03±0.07	0.27±0.74	**3.3**
1.29±0.8	0.14±0.4	0.64±0.8	0.28±0.1	0.08±0.01	0.5±0.6	**3.2**
3.48±4.11	0.39±0.6	0.54±0.3	0.17±0.06	0.02±0.06	0.07±0.4	**3.1**
0.58±1.6	0	0.59±1.13	0.29±0.14	0.08±0.03	0.31±0.9	**3.2**
0	0	0.79±0.5	0.33±0.18	0.11±0.06	0.42±1.22	**3.2**
0.31±1.7	0.07±0.4	0.64±0.3	0.23±0.13	0.07±0.09	0.42±1.2	**1.3**
1.03±0.25	0.29±1.24	0.63±0.11	0.09±0.3	0.06±0.2	0.97±0.9	**1.3**
0.19±1.02	0.12±0.34	0.75±0.6	0.47±0.05	0.15±0.05	0.73±0.3	**1.2**
0	0.4±1.11	1.06±0.5	0.06±0.35	0.09±0.05	1.12±1.3	**1.1**
0.36±2	0.05±0.3	0.98±0.5	0.31±0.04	0.12±0.03	0.09±0.5	**2.3**
0	0.1±0.55	0.84±0.58	0.27±0.3	0.17±0.04	0.4±1.1	**2.1**
0	0	1.03±0.64	0.26±0.07	0.13±0.05	0.08±0.42	**2.1**
0.85±2.5	0.13±0.7	0.6±0.24	0.27±0.25	0.1±0.2	0.16±0.9	**3.2**
0.99±2.9	0.09±0.51	0.84±0.4	0.33±0.22	0.11±0.06	0.2±1.1	**2.3**
1.18±3.3	0	0.81±0.13	0.24±0.1	0.12±0.05	0.35±1.15	**2.3**
0.59±1.63	0.1±0.29	0.68±0.24	0.34±0.6	0.11±0.05	0.28±0.8	**1.3**
0.69±1.9	0.04±0.24	0.8±1.1	0.12±0.03	0.07±0.05	0.12±0.7	**3.3**

Appendix 4. Description and micrographs of the pottery wares (micrographs: V. Visocka)

Ware type	Samples	Description	Micrograph examples (XPL)		
A	AS19, KIV4, KIV6, KIV9, KIV10, KIV11, KIV19, NA3, NA17	Medium coarse, semi-sorted micaceous clay with fine sand and sand, as well as some additional mineral impurities. Tempered with coarse granitic rock grains (max. avg. size 2.04–3.48 mm), volume added: 11–23 %, semi homogenous, semi-dense. This group consists of nine samples and includes all three settlements, with Ķivutkalns dominating.			
B	AS6, AS13, NA2, NA5, NA7, NA8, NA11, NA12, NA18	Fine, semi-sorted ferriferous clay with some silt, fine sand and sand impurities. Small round iron oxide concretions are common (size <1 mm). Tempered with medium coarse granitic rock grains (max. avg. size 1.74–2.79 mm), volume added: 5–16 %, not homogenous, sparse. One sample (AS6) contains a carbonate concretion (size ~ 3 mm). This group consists of nine samples, with only Asva and Narkūnai represented, of which the latter dominates.			
C	AS3, AS7, AS8, AS9, AS11, AS12, AS14, AS16	Fine, sorted micaceous, ferriferous clay with silt, fine sand and additional mineral impurities. Tempered with fine granitic rock grains (max. avg. size 0.93–1.83 mm), volume added: 6–15 %, homogenous, semi-dense. This group consists of eight samples and is only recorded for Asva vessels. Half are identified as fine ware according to their morphological features, the others as coarse ware.			

D	KIV1, KIV5, KIV14, KIV15, KIV17, KIV20, NA14	Medium coarse, sorted silty clay with little sand and additional mineral impurities. Tempered with coarse granitic rock grains (max. avg. size 1.80–4.32 mm), volume added: 15–32 %, homogeneous and dense. In one sample (KIV15) two mixed clays can possibly be distinguished. This group consists of eight samples, mainly from Ķivutkalns; only one sample is from Narkūnai.	  
E	AS4, AS5, AS17, NA1, NA6, NA10, NA16	Fine, semi-sorted ferriferous clay with some sand impurities. Tempered with medium coarse granitic rock grains (max. avg. size 1.74–2.97 mm), volume added: 10–20 %, homogenous, semi-dense. This group consists of seven samples from Asva and Narkūnai.	  
F	AS1, AS2, AS10, AS15, NA13	Fine, sorted ferriferous clay with few silt and sand impurities. Tempered with medium coarse granitic rock grains (1.98–2.9 mm), volume added: 11–17 %, homogenous, semi-dense. This group consists of five samples, mainly from Asva; only one sample is from Narkūnai.	  
G	KIV2, KIV3, KIV8, KIV16	Coarse, unsorted micaceous, silt- and sand-rich clay with accessory mineral impurities. Tempered with medium coarse granitic rock grains (max. avg. size 1.5–2.80 mm), volume added: 10–25 %, not homogenous, dense. One sample (KIV16) possibly contains carbonate concretions (<1 mm). This group consists of four samples from the Ķivutkalns settlement.	  

H	AS18, KIV12, NA9	Coarse, unsorted silt- and sand-rich clay with additional mineral impurities. Tempered with fine granitic rock grains (max. avg. size 1.47–2 mm), volume added: 8–11 %, not homogenous, sparse. This group consists of three samples from all settlements.	  
I	NA4, NA15	Fine, unsorted micaceous silty clay with few quartz sand impurities. Tempered with coarse granitic rock grains (max. avg. size 2.07–2.13 mm), volume added: 10 %, semi homogenous, semi dense. This group consists of two samples from the Narkūnai settlement.	 
J	AS20	Fine, sorted micaceous, ferriferous clay with iron oxide concretions (<1 mm). Tempered with coarse quartz sand, volume added: 9 %, homogenous, semi dense. This group consists only of one sample from Asva.	
K	KIV7	Fine, sorted micaceous, calciferous clay with iron oxide concretions and quartz sand impurities. Tempered with coarse granitic rock grains (max. avg. size 2.9 mm), volume added: 30 %, homogenous, dense. This group consists only of one sample from Ķivutkalns.