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# LATE MESOLITHIC NARVA STAGE IN ESTONIA: POTTERY, SETTLEMENT TYPES AND CHRONOLOGY

This paper gives a systematized overview of different Narva stage sites in Estonia, describing their artefactual and archaeozoological material, and environmental conditions. We demonstrate the diversity of Narva stage settlement types (sites on coastal river estuaries, coast, coastal lagoons, inland river banks and shores of inland lakes) and economy (marine, terrestrial/inland aquatic and mixed subsistence) in the region. A further site-based description of Narva pottery is also provided in order to exemplify the similarities and differences of this earliest pottery type in the eastern Baltic. We also present a comprehensive list of all currently available Narva stage radiocarbon dates from Estonia and Ingermanland (north-western Russia) according to which the Narva-type pottery in the northern part of its distribution area dates to the period c. 5200–3900 cal BC. Additionally, the issues of dating food crust, especially the high risk of reservoir effect offsets, are emphasized. We carried out a comparative study dating contemporaneous food crusts and plant remains and conducting lipid residue analysis employing combined methods of gas chromatography-mass spectrometry (GC-MS) and isotope ratio mass spectrometry (GC-C-IRMS, EA-IRMS). The results demonstrate the implications and importance of characterizing lipid residues so that samples with reservoir correction can at least be identified.

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## Introduction

The beginning of pottery use is a substantial and important innovation in the history of humankind. It must have brought along a new concept not only for storage and cooking, but also changes in technology and production skills, transport and trading. The earliest pottery known to date is from eastern Asia (China, Japan and Russian Far East and eastern Siberia) and goes back to the end of the Pleistocene (e.g. Nakamura et al. 2001; Kuzmin 2006; Boaretto et al. 2009; Shevkomud & Yanshina 2012, 53).

In the Baltic Sea region pottery first appears, depending on traditions of archaeological periodization, in the Early Neolithic (Finland, Russia, Latvia, Lithuania, Belarus) or Late Mesolithic period (Sweden, Denmark, Germany, Poland, Estonia) (e.g. Loze & Lijva 1989; Girininkas 2005, 105 f.; Kriiska 2009, fig. 5; Piezonka 2012, 24). Earlier in Estonia the introduction of pottery was assigned to the Neolithic period, as with other Baltic States (e.g. Jaanits et al. 1982, 61; Lang & Kriiska 2001, 89). Since the adoption of pottery generated no significant change in the local settlement pattern, subsistence economy nor, presumably, in social organization, the new periodization of the Stone Age in Estonia proceeds from the process of the introduction of domesticates. The latter occurred more than a thousand years after the adoption of pottery and resulted in major shifts in the society, settlement and economy in both Estonia and neighbouring areas (Kriiska 2009, 167; Nordqvist et al. 2015, 143).

Two major pottery traditions, divided into many sub-variants, can be distinguished in the Baltic Sea region. One of the traditions embraces pottery types that comprise large pointed- or rounded-bottomed pots and, in places, also small and shallow saucer-shaped vessels (see e.g. Hallgren 2004, fig. 1). The know-how of making such vessels spread from the late 6th millennium through the early 5th millennium cal BC (e.g. Loze 1988, 101; Hallgren 2004, 136 f.; Piezonka 2008, 76; 2012, 42; Girininkas 2009, 127; Kriiska 2009, 161; Jennbert 2011, 99; Pesonen et al. 2012). Five types of early pottery are traditionally distinguished in the Baltic Sea region: (1) Ertebølle in southern Scandinavia, northern Germany and northern Poland (e.g. Hallgren 2004, 135; Jennbert 2011); (2) Early comb ware (or Sperrings) in southern Finland and north-western Russia (e.g. Luho 1957; German 2002); (3) Säräisniemi 1 in northern Finland and in Karelia, the Kola Peninsula in Russia and northern Sweden (e.g. Torvinen 2000; Haggrén et al. 2015, 57); (4) Narva in Lithuania, Latvia, Estonia, north-western Russia and Belarus (e.g. Jaanits 1968; Zagorskis 1973; Yanits 1984; Girininkas 1985; Loze & Lijva 1989; Timofeev 1989; Kriiska 1997b; Brazaitis 2002; Chernyavskij 2012) and (5) Dubičiai (formerly Nemunas) in southern Lithuania, Belarus and north-eastern Poland (e.g. Piličiauskas 2002; Girininkas 2005, 138; 2009, 134 ff.) (Fig. 1). These pottery types clearly differ in terms of both shape and decoration from the second tradition, i.e. linear band pottery that prevailed in mainly the southern Baltics since the late 6th millennium cal BC (Hallgren 2004, 140; Czerniak &

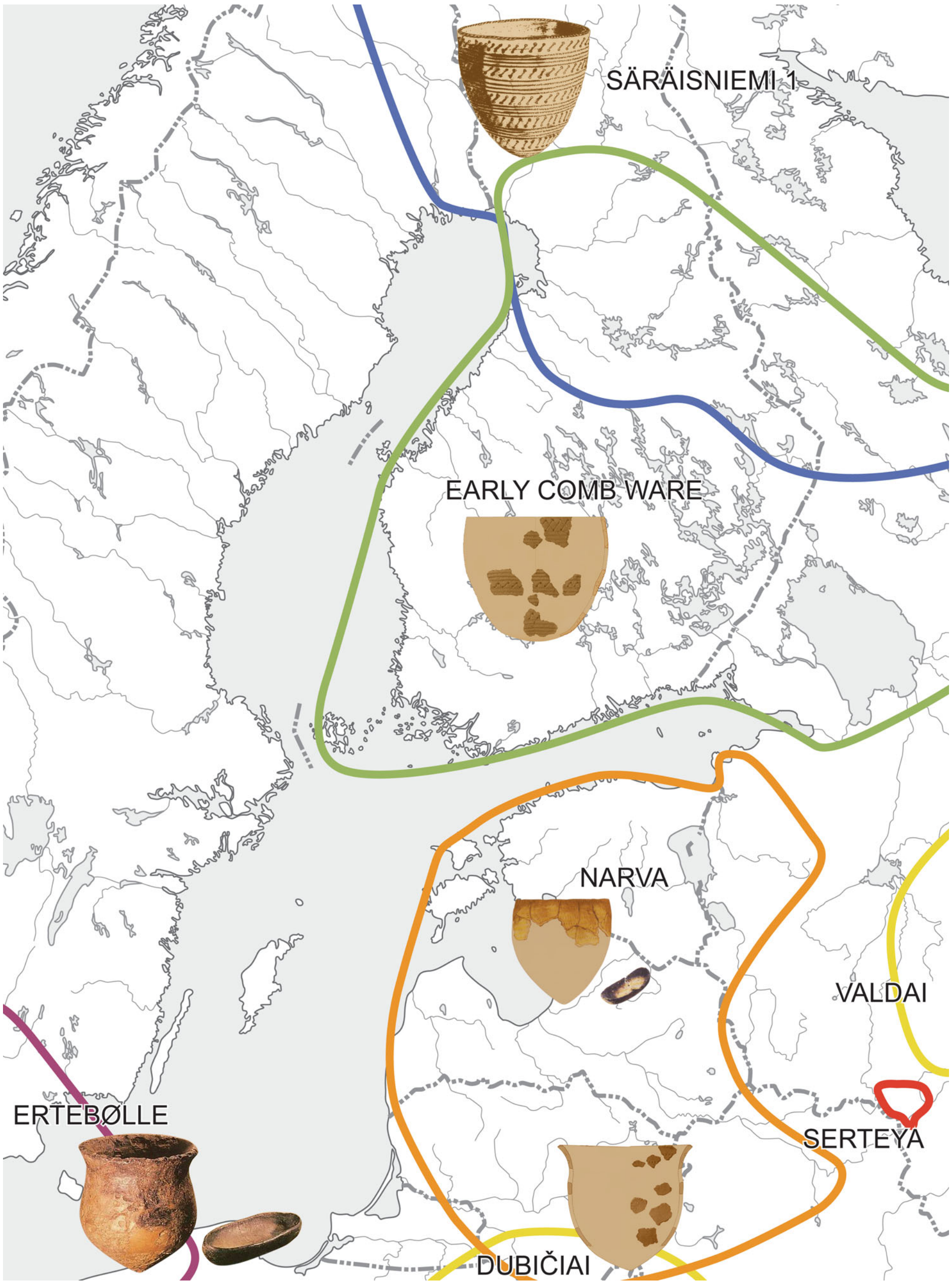


**Fig. 1.** Distribution of the earliest pottery types around the Baltic Sea (base: Timofeev 1989, fig. 1; Burenhult 1999, fig. 54; Huurre 2003, 191; Kriiska 2004, 215; Kriiska & Tvauri 2007, 49; Hallgren 2008, fig. 4.7; Müller 2011, fig. 7; Chernyavskij 2012, fig. 1; Vitenkova 2012; Haggrén et al. 2015, 57, vessels by Jennbert 1999, 263; Nordqvist & Kriiska 2015, fig. 2; Piezonka 2015, figs 199–202, Plate 2, 46). Map by Aivar Kriiska, technical realization Kristel Roog.

Pysel 2011, 349), and also from funnel beaker vessels of the final 5th millennium BC (e.g. Jennbert 2011, 99; Czerniak & Pysel 2011, 348; Czekaj-Zastawny et al. 2013, 425). Therefore, it has been suggested that, in contrast to later pottery types, pointed-bottomed vessels and low plates/oval dishes/lamps are related to the pottery tradition of not the Near East but eastern Asia (e.g. Hallgren 2004, 141; Czerniak & Pysel 2011, 348; Hartz et al. 2012).

As mentioned above, in the eastern Baltics the know-how of pottery making was introduced in the late 6th millennium cal BC. Two main types of early pottery are commonly distinguished in this region, the so-called Narva and Dubičiai (Nemunas) types. The earliest radiocarbon dates associated with the Narva-type pottery cluster around c. 5500 cal BC and come from organic remains recovered from the occupation layers of the settlement sites at Zvidze and Oza in eastern Latvia (Loze 1988, 101). The burnt crust of a vessel found from Kääpa in Estonia yielded a similar date (Piezonka 2008; Table 1), but in this case isotope data hint at a possible freshwater reservoir effect (Piezonka et al. 2016, see discussion below). Reliable radiocarbon dates from burnt animal bones and charcoal in settlement layers containing Narva-type pottery that point to c. 5200/5000 cal BC are known at several sites in both Estonia and north-western Russia (Table 1; Kriiska & Nordqvist 2012, fig. 10; Rosentau et al. 2013, table 2; see also discussion in chronology part). As for the end dates, in the southern part of eastern Baltics the designation of Narva-type pottery is extended to the pottery tradition that continued until c. 1750 cal BC (Girininkas 2005, 118), whereas in the northern part of its distribution area c. 3900 cal BC is considered the youngest date of the type (Kriiska & Nordqvist 2012, fig. 10).

The earliest ceramics in the eastern Baltic region have been thoroughly studied by applying stylistic, typological, technological and petrographic, as well as chemical analysis of clays and tempers (e.g. Gurina 1967; Kriiska 1995b; 1996c; 1996d; 2008; Kalm 1996; Kalm et al. 1997; Brazaitis 2002; Mikšaitė 2005; Dumpe et al. 2011; Piezonka 2012). Based on the shape and size of the vessels and the occurrence of charred crust on the vessels' interiors, both storing and cooking have been proposed for the function of the Narva-type vessels in Estonia (Kriiska & Tvauri 2007, 53 f.). However, direct lipid residue analysis of earliest pottery contents and its influence on chronology-related discussions, which are debated issues in the western Baltic archaeology (Craig et al. 2011; Heron et al. 2013), is currently missing.

The main aim of this article is to present a structured overview of the Late Mesolithic Narva stage in what is today Estonia, covering the characteristics of Narva-type pottery, different settlement types, a short description of main sites, and their archaeozoological material, and the overall chronology of the Narva stage in northern part of its distribution area. We focus on the most thoroughly studied Narva sites with well-preserved material, which also represent a variety of different geographical locations where Narva stage has been identified. Faunal remains found therein and the environmental location of the sites under discussion

**Table 1.** Narva-stage radiocarbon dates from the northern part of the pottery distribution area (Estonia and Ingermanland). Dates from Tartu (TA) and Tallinn (Tln) are conventional, the rest are AMS dates

| No. | Site | Soil | Material | Lab. No. | $^{14}C$ age | Calibrated date (cal BC, 95% probability unless stated) | First publication |
|---|---|---|---|---|---|---|---|
| 1 | Narva Joaorg, layer C | Sand | Charcoal from fire place | TA-33 | 5820 ± 200 | 5220–4320 | Ilves et al. 1974, 175 |
| 2 | Narva Joaorg, layer C | Sand | Charcoal from fire place | TA-7 | 5300 ± 250 | 4710–3630 | Ilves et al. 1974, 175 |
| 3 | Vihasoo III | Sand | Calcined ringed seal bone from cultural layer of dwelling site (AI 6038: 49) | Poz-58930 | 5895 ± 35 | 4850–4690 | This study |
| 4 | Kõpu IA | Sand | Charcoal from fire pit | Le-5452 | 5575 ± 50 | 4510–4330 | Kriiska 2002, table 1 |
| 5 | Kõpu IA | Sand | Charcoal from fire pit | Tln-1871 | 5370 ± 68 | 4350–4040 | Kriiska 1995a, table 3 |
| 6 | Kõpu IA | Sand | Charcoal from fire pit | Tln-1898 | 5464 ± 96 | 4490–4050 | Kriiska 1995a, table 3 |
| 7 | Kõpu IA | Sand | Charcoal from fire pit (1981 test excavation) | TA-1493 | 5530 ± 90 | 4590–4220 (93%) | Kriiska 1995a, table 3 |
| 8 | Kõpu IA | Sand | Charcoal from fire pit | TA-2686 | 5460 ± 100 | 4500–4040 | Kriiska 2002, table 1 |
| 9 | Kõpu IA | Sand | Charcoal from fire pit (N/14-15-16) | Tln-1873 | 5604 ± 52 | 4540–4340 | Kriiska 1995a, table 3 |
| 10 | Kõpu IA | Sand | Charcoal from fire pit | Tln-1901 | 5698 ± 70 | 4710–4370 | Kriiska 1995a, table 3 |
| 11 | Kõpu IA | Sand | Carbonized organic remains on potsherd (AI 6007: 1734) | Hela-843 | 5540 ± 55 | 4500–4320 (93%) | Kriiska et al. 2005, 16 |
| 12 | Kõnnu | Sand | Skull fragment of the ringed seal found from cultural layer of dwelling site | Poz-30039 | 6460 ± 40 | (Depends on marine reservoir effect) | This study |
| 13 | Riigiküla VI | Sand | Calcined terrestrial mammal bone from cultural layer of dwelling site | Hela-1909 | 6130 ± 45 | 5220–4950 | Kriiska & Nordqvist 2012, fig. 10 |
| 14 | Riigiküla IV | Sand | Charcoal from cultural layer of dwelling site | Tln-1989 | 6023 ± 95 | 5210–4720 | Kriiska 1996a, 416 |

**Table 1.** *Continued*

| No. | Site | Soil | Material | Lab. No. | $^{14}C$ age | Calibrated date (cal BC, 95% probability unless stated) | First publication |
|---|---|---|---|---|---|---|---|
| 15 | Riigiküla IV | Sand | Charcoal from fire pit | Tln-1990 | 5624 ± 115 | 4730–4240 | Kriiska 1996a, 416 |
| 16 | Riigiküla IX | Sand | Charcoal from cultural layer | Tln-1890 | 5469 ± 111 | 4540–4040 | Kriiska 1995b, 454 |
| 17 | Riigiküla XII | Sand | Charcoal from cultural layer | Tln-1992 | 5268 ± 58 | 4250–3970 | Kriiska 1999, table 1 |
| 18 | Lommi III | Sand | Calcined mammal bone from cultural layer of dwelling site (AI 3867: 436) | Beta-309096 | 5820 ± 30 | 4780–4580 | Rosentau et al. 2013, table 2 |
| 19 | Kääpa | Sand under the peat | Carbonized organic remains on potsherd (AI 4245: 2008) | KIA-35897 | 6540 ± 40 | 5620–5460 (92%) | Piezonka 2008, 76 f. |
| 20 | Kääpa | Sand under the peat | Carbonized organic remains on potsherd (AI 4245: 2039) | KIA-33921 | 5985 ± 35 | 4990–4780 | Piezonka 2008, 76 f. |
| 21 | Kääpa | Sand under the peat | Tooth (molar) of the wild horse found from cultural layer of dwelling site | KIA-35737 | 5698 ± 73 | 4790–4550 | Sommer et al. 2011, table 1 |
| 22 | Kääpa | | Foodcrust Kä-2007/26 | KIA-49792 | 5798 ± 21 | 4720–4580 | Piezonka et al. 2016 |
| 23 | Kääpa | | Foodcrust Kä-2007/62 | KIA-49793 | 6015 ± 35 | 5000–4800 | Piezonka et al. 2016 |
| 24 | Kääpa | | Foodcrust Kä-2007/36 | KIA-49794 | 6320 ± 30 | 5360–5220 | Piezonka et al. 2016 |
| 25 | Kääpa | | Foodcrust Kä-2007/45 | KIA-49795 | 6219 ± 25 | 5300–5060 | Piezonka et al. 2016 |
| 26 | Kuzemkino 1 | Sand | Calcined fox bone from cultural layer of dwelling site | Hela-1945 | 5090 ± 40 | 3970–3790 | Kriiska & Nordqvist 2012, fig. 10 |
| 27 | Galik 3 | Sand | Calcined terrestrial mammal bone from cultural layer of dwelling site | Hela-2743 | 5442 ± 45 | 4370–4220 (93%) | Rosentau et al. 2013, table 2 |
| 28 | Izvoz 2 | Sand | Calcined terrestrial mammal bone from cultural layer of dwelling site | Hela-2742 | 6212 ± 48 | 5310–5040 | Rosentau et al. 2013, table 2 |
| 29 | Kunda Lammasmägi, mixed upper layer | Humus Moraine | Elk bone | TA-12 | 6015 ± 210 | 5380–4450 | Lijva et al. 1965 |

help to expand our understanding of particular subsistence economies of the early pottery users in Estonia. To address the chronology of the Narva stage and early pottery arrival in Estonia we provide detailed information on the radiocarbon dates obtained so far (thirty-four conventional and AMS dates from Estonia and Ingermanland, including some previously unpublished results; Tables 1 and 3) with five additional and recent dates obtained as part of a wider study of lipid residues in Estonian Narva stage pottery (Oras et al. 2017). As part of the chronology discussion we also exemplify the importance of identifying lipid residues when dating food crusts.

## Narva-type pottery in eastern Baltics

Narva-type pottery is a generic designation for a pottery tradition that spread across an extensive area in Eastern Europe. The early (6th and 5th millennium cal BC) pottery is relatively uniform in Estonia, Latvia, Lithuania, north-western Russia and Belarus. Researchers agree that in the eastern Baltic region, the adoption of pottery was a cultural loan, since the rest of the material culture appears to be a continuation of the existing local traditions (e.g. Jaanits 1970, 86; Zagorskis 1973, 65; Girininkas 1994, 259; Marcinkevičiūtė 2005, 200; Kriiska 2009, 161 f.; Piezonka 2012, 46). Continuity is also observable in subsistence practices and the settlement pattern. On the other hand, Narva-type pottery encompasses several local variants (e.g. Yanits 1984; Girininkas 1985; 1994; Loze 1985; Timofeev 1989; Kriiska 1997b) or styles (Brazaitis 2002), which have been thought to have resulted from different foreign influences (Jaanits et al. 1982, 67; Girininkas 1985, 121 ff.) or from local specific features that had existed before the introduction of pottery (Kriiska 1997b, 17; Brazaitis 2002, 70).

Regardless of some variation, the early pottery in the eastern Baltics shares a series of common traits. Narva-type vessels were usually made from narrow clay coils, often no more than 1–2 cm in width. The junctions of the coils are predominantly of concave–convex type (i.e. U-type), less often diagonal (N-type) or straight (H-type) (e.g. Gurina 1967, 34; Loze 1988, 48 f.; Kriiska 1995b, 66 f.). The bottom parts of the vessels have been formed from a single lump of clay. The vessels come in two main shapes: 1) half egg-shaped pots with straight or slightly curved walls and pointed (incl. nipple-like protrusion) or, less frequently, rounded bottoms, and 2) elongated or rounded bowls (e.g. Vankina et al. 1973, 211; Loze 1988, 49; Kriiska 1997b, 18; Fig. 2). Rims are usually as thick as or thinner, rarely thicker, than walls (Kriiska 1997b, 18; Brazaitis 2002, figs 2–4). The fabric shows region-based differences in the choice of temper, comprising crushed shells (*Unio tumidus* and *Anodonta cygnea* in Estonian specimens; Kriiska 1996d, 374) or chopped plants, less frequently rock debris (Vankina et al. 1973, 211; Kriiska 1996d, 374) or sand (Yanits 1984, 20; Loze 1988, 48; Kriiska 1995a, 412). Surface finish of the vessels also varies, even among the roughly

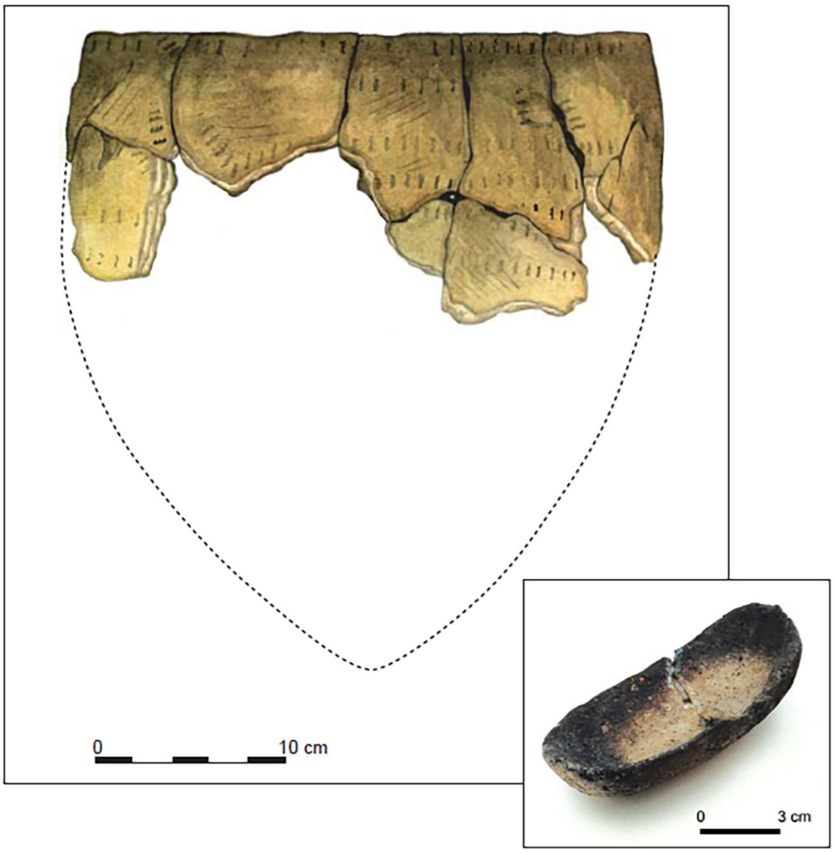


**Fig. 2.** Reconstruction of the Narva-type egg-shaped pot (AI 4245) and elongated bowl (AI 4245: 1419) from Kääpa site. Drawing by Diana Selli and photo by Kriiska et al. 1999.

contemporaneous specimens of a single site, and comprises striation, smoothing and even slight burnishing (e.g. Loze 1988, 48; Kriiska 1995b, 71; Fig. 3).

Regional variation of the Narva-type pottery is most clearly expressed in the decoration. Vessels with the most abundant and diverse decoration can be found in eastern Latvia and south-eastern Estonia, whereas the least decorated vessels appear on the islands of western Estonia. A portion of the pottery bears impressions of a serrated stamp (so-called comb impressions) and various notches, hollows and grooves (e.g. Vankina et al. 1973, 211; Loze 1988, 49 ff.; Kriiska 1995b, 65). Decoration of a vessel is mostly limited to its upper part and to only one decorative motif (Vankina et al. 1973, 211; Kriiska 1995b, 72). In the eastern Latvian pottery, the dominant motif is small regular notches and hollows, which have been arranged in zones and often form geometric designs (e.g. Loze 1988, 49 ff.). The vessels used in the area of Estonia often feature comb impressions, and particularly the northern Estonian Narva-pottery is known for the so-called walking-comb motif

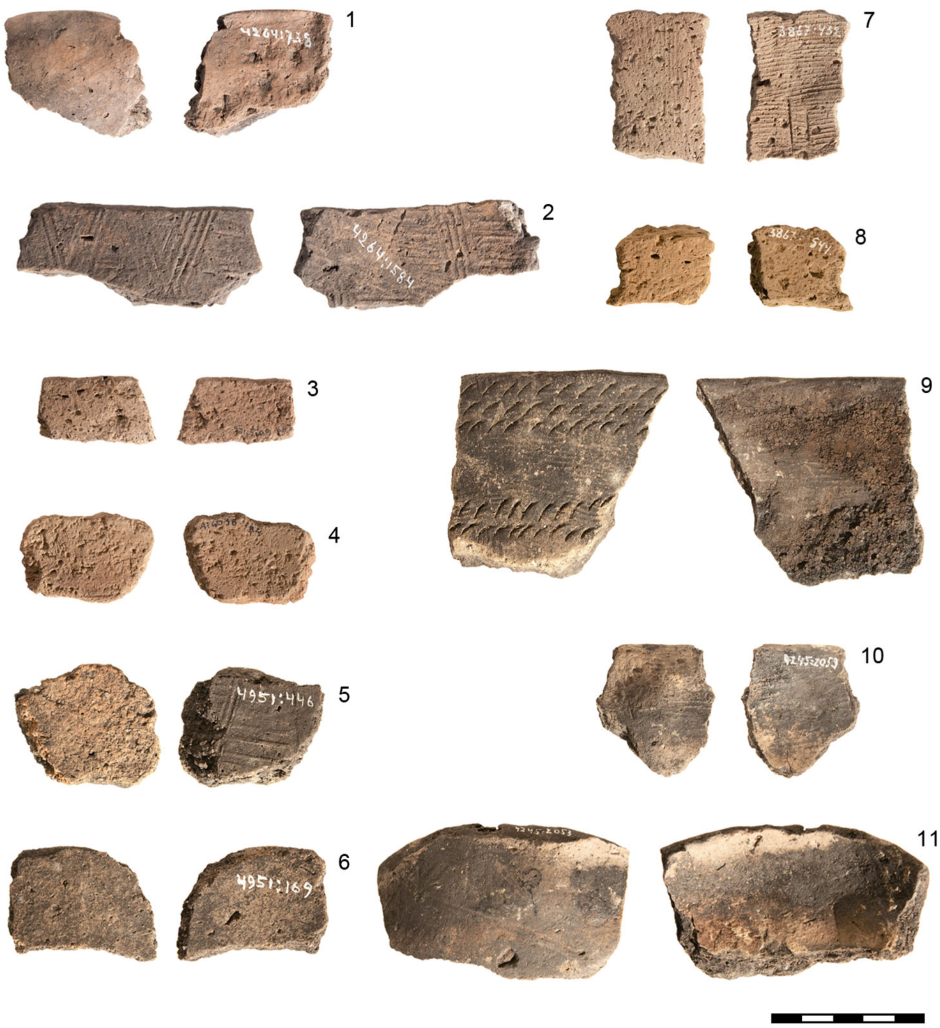

**Fig. 3.** Narva type pottery sherds (bowl – 1 and 11; pots – 2–10) from Narva Joaorg (1–2), Vihasoo III (3–4), Kõnnu (5–6), Lommi III (7–8) and Kääpa site (9–10). (AI 4264: 738 and 1584; 6038: 126 and 184; 4951: 446 and 169; 3867: 432 and 544; 4245: 239, 2059 and 2053). Photos by Kristel Roog.

(Kriiska 1995b, 73), which was made by holding one end of the comb firmly in place while dragging the other end gently along the surface of the vessel. In eastern Latvia comb impressions occur to some extent, but farther southwards notches are in clear dominance (Loze 1985, 14 f.). A unique trait of the vessels on the islands of western Estonia is a row of deep hollows in the rim area (Yanits 1984, 20; Kriiska 1995a, 413). In north-eastern Estonia shells of river mussel were serrated and used for creating comb impressions on pottery. It is possible that the exterior surfaces of some Narva-type vessels were painted red with ochre (Kriiska & Tvauri 2007, 53). Firing temperature of the pottery was usually below 800 °C (Kriiska 1995b, 74).

The majority of the Narva-type vessels found in Estonia are ordinary pots that were presumably used for storage and cooking. As the evidence of cooking, the presence of burnt organics on the interior surfaces of the pots has been emphasized (e.g. Kriiska & Tvauri 2007, 53 f.; Loze 2000, 213). Smaller bowls are in clear minority. Besides the exceptional Narva Joaorg site which has provided several examples of oval bowls, most of the bowl-type vessels are known from the south-eastern part of the Estonia, and they resemble the contemporary eastern Latvian counterparts (Loze 1988, 48).

## Narva-stage settlement types in Estonia and Ingermanland and description of the major sites

The Narva-stage settlement sites represent five characteristic locations of dwelling and camp sites in the eastern Baltic region: 1) coastal river estuaries (Vihasoo III and Narva Joaorg in this article); 2) coast (Kõnnu and Kõpu IA); 3) coastal lagoons (Riigiküla IV and VI and Lommi III); 4) inland river banks (Kääpa); 5) shores of big inland lakes (Kalmaküla) (Fig. 4). The available radiocarbon dates (Table 1, Fig. 7) demonstrate that the differences between these groups are regional and not chronological.

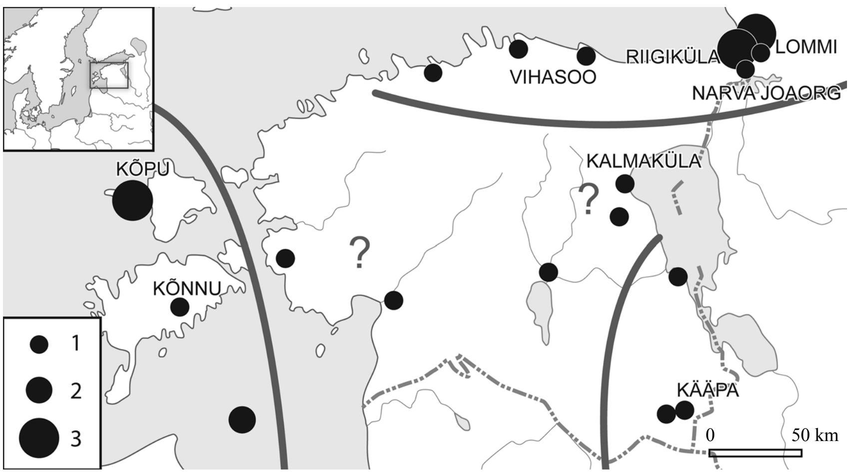


**Fig. 4.** The sites of Narva stage in Estonia and Ingermanland (Russia). 1 one settlement site, 2 from two to five settlement sites, 3 six or more settlement sites. Black solid line marks local variants of Narva-type pottery. The question mark in western and eastern Estonia indicates that the local pottery group on these areas is unclear. Map by Aivar Kriiska, technical realization Kristel Roog.

## Settlement sites at river estuaries

The estuaries where rivers flow into the Baltic Sea were important nodes in the Stone Age settlement pattern in Estonia and most probably also elsewhere in the region (e.g. Kriiska & Lõugas 2009; Vaneeckhout et al. 2012, 60). The coastal settlement and sea-oriented economy evolved in the Baltic Sea region, including Estonia, during the 8th millennium cal BC (e.g. Andersen 1993, 66 f.; Larsson 1997; Krijska 2008). In the early stage of this coastal settlement era river banks up to a few kilometres from the river mouth were preferred, but later the settlements were frequently located directly at the river mouths (e.g. Larsson 1997; Rosentau et al. 2011). The settlement sites discussed below include both sub-types.

### *Narva Joaorg*

The settlement site Narva Joaorg, together with the nearby (Narva) Riigiküla settlements, is a site that gave name to the Narva-type pottery. It is situated on the bank of the Narva River in north-eastern Estonia, in a location that in the Stone Age was a coastal river estuary. The site was found in 1953 and excavated in 1954, 1957, 1960 and 1962–1964 (Jaanits et al. 1982, 43; Kriiska 1996c, 361). It was a multi-layer site with deposits from the Mesolithic to the Viking Age, and Narva-type pottery was present in more than one stratigraphic layer. A small proportion of the sherds was collected from the uppermost layer along with finds from the Iron Age and historical era. The majority of the Narva-type pottery, however, was found from beneath this layer, from layer B. The upper part of this layer contained also Comb and Corded ware sherds and even slightly later finds, but the lower part yielded unvaryingly the Narva-type pottery (Jaanits 1965, 37). Single sherds were also observed in the lower-lying layer C, which was separated from layer B by a sterile layer of sand and provided charcoal radiocarbon-dated to an average of 5th millennium cal BC[1] (Fig. 7). Excavation of layer C also exposed around ten hearths, whereas only one hearth was found in the lower part of layer B (Yanits 1966, 122). Associated with the Narva stage is probably also a poorly preserved skeleton of a child (Jaanits et al. 1982, 45).

The majority of finds associated with the Narva stage are quartz objects and debitage, although bone artefacts such as arrowheads, fishing spearheads and adzes, are also relatively numerous (Jaanits 1965, 37). The Narva-type pottery assemblage includes pots as well as a few elongated bowls (Kriiska 1995b, 69; Fig. 3: 1–2). The fabric of the ceramics contains mainly organic inclusions (some vegetal matter) and shell debris, although occasionally mineral inclusions were also observed. The vessels have been coil-built from narrow clay coils with U- and N-type junctions. Surfaces of the vessels have been smoothed, less frequently striated, and decoration is generally modest.

[1] If there is no other reference, dates are calibrated by OxCal v4.2 (Bronk Ramsey 2009; 2013), using IntCal13 atmospheric curve (Reimer et al. 2013).

The site yielded an abundance of faunal remains. The Narva stage is best characterized by the finds made from layer C, which indicate a diverse species composition and provide an excellent representation of the hunted game (e.g. Paaver 1965, 437 f.; Lõugas 1996, 370 f.). The Narva stage coincided with and follows the Atlantic climatic optimum, when broad-leaf forests dominated here instead of boreal (taiga) forests and the species richness is therefore thought to have peaked in this period. The remains of game hunting at the site include the whole range of ungulates characteristic of the period: elk (*Alces alces*), aurochs (*Bos primigenius*), red deer (*Cervus elaphus*), roe deer (*Capreolus capreolus*) and wild boar (*Sus scrofa*). Carnivores are less well represented, while beaver (*Castor fiber*) was typical. A few bones of seals are evidence of seal hunting and the bird bones are dominated by water fowls. Fishing was as important as game hunting: mainly pike (*Esox lucius*), pikeperch (*Sander lucioperca*) and wels catfish (*Silurus glanis*) were captured, but probably also different cyprinids (Cyprinidae) and perch (*Perca fluviatilis*). Their scarcity in the bone assemblage was probably caused by the collection method during the excavation where no sieves were used.

### *Vihasoo III*

Settlement site Vihasoo III is located on the bank of the Loobu River in northern Estonia. The site was discovered in 1995 and excavated in 1995–1996 (Kriiska 1997a; 1997b). The original locale of the site was a mouth of a coastal river (Kriiska 1997b, fig. 3). The excavated area exposed an 8 m long area with high concentration of finds, interpreted as possibly a base of a dwelling house. Among stone finds, quartz dominates and flint is less frequent. The pottery of Narva type, represented by fragments of pots, contains predominantly organic inclusion (of vegetal origin); in single sherds mineral inclusion (rock debris and sand), sometimes combined with organics, has also been detected (Kriiska 1997a, 14, 16). The pots have been built from generally narrow coils with mainly U-type junctions. The vessels have been conical in shape and capacious, with smoothed, less frequently striated surfaces, and with no decoration (Fig. 3: 3–4). A radiocarbon date of a burnt seal bone dates the settlement site to the first half of 5th millennium cal BC (Fig. 7). The bone assemblage of the site was generally meagre, with at least one bone originating from a seal.

## Coastal settlements

One stage in the development of the Stone Age coastal settlement was the occupation of the coasts that faced the open sea. The majority of such sites in Estonia have been found from western islands which, based on the available archaeological evidence, were colonized in the 6th millennium cal BC (Kriiska 2002, table 2). The Narva-stage settlements were located similarly to and often in the same areas with the settlements of the previous period. Coasts of gulfs, sometimes places in the lee of sand dunes, were frequently inhabited, and the settlements were mostly, with the exception of only the settlements in Saaremaa, seasonal camps of seal hunters. Seasonality determined the nature of subsistence economy in a particular site, and provides probably a more likely explanation than poor preservation for the unvarying composition of faunal assemblages found at these sites. Differently from the previous period, in the Late Mesolithic Narva stage not only ringed seal (*Pusa hispida*) but also grey seal (*Haliachoerus grypus*) hunting was practised (Kriiska & Lõugas 1999, 166).

### *Kõpu IA*

Settlement site IA at Kõpu is situated in the Kõpu Peninsula in the western part of the Island of Hiiumaa. The site, discovered in 1981, was partly excavated in 1981, 1994, 1998 and 2001 (Lõugas 1982; Kriiska 1995a; 1996b; 2003). Palaeoreconstruction (Moora & Lõugas 1995, 473 ff.; Kriiska 2004, 108) shows that the settlement was located on the wind-sheltered south-eastern coast of an islet a few square kilometres in size. Excavation of the site unearthed several hearths recessed in the ground and tightly filled with stones. Stone finds are dominated by items of quartz whereas flint was a less used material (Kriiska 2002, 37). The Narva-type pottery of the site originates from conical pointed-bottomed vessels, the fabric of which contained mostly rock debris and to a lesser extent an organic inclusion (Kriiska & Lõugas 1999, 166). The vessels have been made by coiling narrow clay bands with U-type junctions. The surfaces of the vessels were mostly smoothed, less frequently striated. Only a few per cent of the sherds display decoration, which comprises notches, grooves and hollows. Based on the scatter of eight radiocarbon dates of charcoal and burnt crust on the pottery, the site has been dated to the third quarter of the 5th millennium cal BC (Fig. 7). The invariability in the artefact and faunal assemblages indicates a seasonal, most probably a late winter / early spring camp site of seal hunters. Hunting in spring is evidenced by a bone of a ringed seal only one week old when slaughtered (Moora & Lõugas 1995, 479). Historical records reveal that early spring was also considered the best seal hunting season by the later seal hunters of the Baltic Sea islands and inland Estonia (e.g. Itkonen 1924; Leesment 1931; Art 1988).

The majority of the uncovered bones comes from seals, including the ringed seal and the grey seal. Of bird bones, the numerous representatives of anatids (Anatidae) were accompanied by the more unusual findings of cormorant (*Phalacrocorax carbo*) and white-tailed eagle (*Haliaeetus albicilla*). The presence of hedgehog (*Erinaceus europaeus*) mandibles in a small sea islet suggests travelling with humans rather than independent migration of the species. Evidence of fishing is modest due to poor bone preservation. Soil sieving at excavations, however, recovered 14 specimens of fish bone, although the species determination was possible in only six cases (Moora & Lõugas 1995, 478; Lõugas 1997, 25). Four of such bones came from the cod (*Gadus morhua*), one from turbot (*Scophthalmus maximus*) and one from pike (*Esox lucius*), which suggests that marine fish predominated. Pike may originate from the provisions brought along by the seal hunters from the mainland or, alternatively, its presence shows that salinity of the seawater around the ancient islands may have been sufficiently low for a pike population (pike inhabit also the brackish coastal waters of the Baltic Sea). The clear predominance of seal bones suggests that for the ancient inhabitants of Kõpu fishing was a sideline rather than a major occupation.

### *Kõnnu*

The settlement site at Kõnnu on the Island of Saaremaa was discovered in 1977 when turf removal before gravel mining exposed dark patches of soil characteristic of a settlement site (Pesti & Rikas 1991, 11). Excavation was conducted in 1977–1978, and in 1979–1986 finds were collected from the displaced occupation layer (Jaanits 1979; Lõugas & Selirand 1988, 212). The settlement had been situated on an islet not far from bigger island (Jaanits 1995, 247) and, despite the absence of a precise palaeogeographical reconstruction, its location whether directly on the seashore or at only a slight distance from it is likely. Excavation exposed 140 hollows dug in the subsoil and up to 3 m in diameter. Approximately half of the hollows were hearths, mostly filled with stones, and three of the hollows have been interpreted as possibly the bases of dwellings with at least partly sunken floors (Jaanits 1979, 364). An inhumed skeleton in a crouched position can also be dated to the Narva stage (ibid., 366). An AMS date of a cranial fragment of a ringed seal assigns the site to the end of 6th / beginning of the 5th millennium cal BC (Fig. 7). The presence of a burial, chopping implements in abundance and dog bones (which all are absent from the Narva-stage settlement sites on the islands of Hiiumaa and Ruhnu) suggest a relatively sedentary habitation persisting through several seasons or even throughout the year.

The site yielded numerous stone artefacts, particularly axes and adzes from metamorphic rocks. Small lithic tools were made from quartz or flint. The amount of Narva-type pottery (Fig. 3: 5–6), however, was relatively small in view of the size of the excavated area. The clay vessels, fairly large and half egg-shaped coil-built pots, were made from fabric tempered with rock debris or gravel; they were fired at modest temperatures and are fragile (Jaanits 1979, 367). Unlike the contemporaneous pottery in mainland, the vessels at Kõnnu featured a very modest decoration. The most common motif is rows of deep hollows below the rim; impressions of a serrated stamp and grooves also occur (Yanits 1984, 20).

Similarly to the bone assemblage of Kõpu IA, the material from Kõnnu indicates a pronounced exploitation of ringed seal and, to a lesser extent, grey seal. Single bones from other animals, such as elk, fox (*Vulpes vulpes*), pine marten (*Martes martes*) and beaver, are insignificant in number and do not diminish the importance of seal hunting in the subsistence economy of the inhabitants (Lõugas 1997, appendix IIA; 1999, table 3). Fish bones were poorly preserved and the collection thereof was entirely unsystematic. Unlike at Kõpu IA, the 24 fish bones recorded at Kõnnu include no remains of sea fish; only pike, perch and roach (*Rutilus rutilus*), which inhabit fresh water and in places also coastal brackish water, are represented.

## Settlement sites at lagoons

In the Littorina Sea stage of the Baltic Sea the eastern coastline of the sea was indented to a considerably greater degree than today and featured relatively numerous lagoons (e.g. Saarse et al. 2009; Rosentau et al. 2013; Ryabchuk et al. 2016). An extensive lagoon system was located in what today are the surroundings of Narva and Luga in the Estonian–Russian border zone (Rosentau et al. 2013). Settlements of the area were situated on a barrier island, on a spit (e.g. Riigiküla IV and VI) and on the lagoon-facing mainland coast (e.g. Lommi III). All the lagoon settlements have been located close to the shore, and one could even observe them following the regressing shoreline. Relatively well-preserved faunal remains at the sites show that lagoons and their surroundings in the eastern Baltic area provided varied sources for sustenance (e.g. Lõugas 2008, 258; Lõugas & Tomek 2013).

### *Riigiküla IV and VI*

Settlement sites IV and VI at Riigiküla in north-eastern Estonia are situated on an elevated ridge, which at the time of the settlements was a spit enclosing a lagoon (Rosentau et al. 2013, fig. 7). The sites were located on the lagoon-facing coast of the spit with a distance of only a few hundred metres from each other, but at different heights and in different times – from the end of the 6th millennium to mid of the 5th millennium cal BC (Fig. 7). The first settlement sites at Riigiküla were discovered and excavated in the 1950s and they were among the most important contributors to the discerning of the Narva-type pottery in the eastern Baltics (Gurina 1967). Riigiküla IV was found in 1991 and excavated in 1995; the respective dates for Riigiküla VI are 1994 and 2007–2008 (Kriiska 1995c; 1996a; Krijska 2003). Excavation at Riigiküla IV exposed three hearths.

Despite the difference in date the find assemblages of the two sites are similar. Stone finds were predominantly of quartz and to a lesser degree of flint, and comprised both tools and debitage. The assemblage of Narva-type pottery comprises fragments from only pointed-bottomed vessels, which in most cases have fabrics tempered with vegetal inclusion, less often with shell debris or some mineral matter (Kriiska 1996a, 411). The vessels have been built from narrow clay coils which mostly display junctions of U-type, less frequently of N- or H-type. The surfaces of the vessels were striated or smoothed and a few pots had upper parts decorated with comb impressions, hollows, pits, grooves, etc.

At both sites bone preservation was poor and only a few pieces of burnt animal bone were recovered. The faunal remains of Riigiküla IV, however, provided some insight into the taxonomic composition, although the small sample size does not allow deciding which animals were the most prominent in the subsistence economy of the inhabitants. The fauna was similar to the fauna observed at Narva Joaorg, though the bone assemblage is smaller and therefore includes fewer species. On the other hand, another marine mammal besides seals, a porpoise (*Phocaena phocaena*), is present at Riigiküla. Regardless of the small amount of the remains it seems likely that the proportion of marine and terrestrial mammals in the subsistence economy was similar to the pattern observed at Narva Joaorg and in other settlements at Riigiküla. Of birds, mainly water fowl of the Anatidae family were hunted. An average-sized raptor, a hawk or an eagle, is present in the assemblage as well. The ichthyofauna of the site also resembles its counterpart at Narva Joaorg, as it includes pike, pikeperch, wels catfish, perch and a few cyprinids (Lõugas 1997, 187).

### *Lommi III*

Settlement site III at Lommi is situated in western Russia a few kilometres from the Estonian–Russian border (before WWII the territory of Estonia). It was found in 1939 and excavated in 1940 (Indreko 1948). The site was occupied recurrently and yielded pottery of Narva-type and comb ware (Kriiska 1995b, 60). In the Narva stage the settlement was located on mainland coast facing a large lagoon (Rosentau et al. 2013). Excavation produced only about a dozen sherds of Narva-type ceramics (Fig. 3: 7–8), all from pot-shaped vessels, but the Narva-stage date is attested by also a burnt animal bone AMS-dated to first half of 5th millennium cal BC (Fig. 7). The fabric of all potsherds had been vegetal-tempered and the vessels had been built from narrow coils with U-type junctions; none of the sherds bear decoration (Kriiska 1995b, 72). The site also yielded a few burnt animal bones which, however, have not undergone a specialist analysis. Since the site was occupied in different periods, the bones could potentially not be used in the study of a particular period without radiocarbon dating.

## Settlement sites on inland river banks

The shores of the rivers have been inhabited throughout the eastern Baltics during the whole Stone Age period. From Estonia are known dozens of settlements sites located on the large and even small river banks (Kriiska & Tvauri 2007, 20), but with the Narva stage material is up till now only two sites – Kääpa and Villa in south-eastern Estonia.

### *Kääpa*

The settlement site at Kääpa is situated on the bank of the Võhandu River in south-eastern Estonia. It was found in 1959 and excavated in 1959–1962 and 1974 (Yanits 1976). The majority of the site's middle part has been excavated.

The settlement had emerged in the flood plain of the river probably in the first half of the 5th millennium cal BC (Fig. 7 and discussion), at the time when the river's water level was somewhat lower than today. Later on the water level rose and the flood plain together with the cultural layer of the settlement was covered by peat. The site is multi-layered and contains besides the Narva-type pottery also comb and corded wares. Due to good preservation conditions at the site numerous antler and bone artefacts have survived. Small implements recovered from the site are of flint or quartz. Only one poorly preserved hearth has been found (Jaanits et al. 1982, 63).

The fabric of the site's Narva-type pottery (Fig. 3: 9–11) contains mostly shell debris and less often some vegetal matter (Jaanits et al. 1982, 64). The vessels had been formed from coils with predominantly U-type junctions. They were usually conical in shape and rather large with the openings up to 45 cm across, though fragments of small elongated bowls are also present (Fig. 2). Surfaces of the vessels were often striated. Only a portion of the vessels bore decoration, which was arranged in distinctive zones in the upper part of a vessel and consisted of comb impressions, small hollows, notches or grooves. Usually no more than one decoration element was applied on a vessel. The most frequent decoration elements are comb impressions which have been left by the so-called walking comb. Often a vessel features several horizontal zones, one below the other, of this motif. Small hollows and notches often occur in rows or groups. Few vessels have been decorated with small circles, and grooves are even less frequent. Some sherds display grooves which were probably incised with the edge of a shell and formed a latticed pattern.

Faunal remains are well-preserved and diverse. The assemblage is dominated by species of temperate broad-leaf and mixed forests, such as elk, red deer, aurochs, wild boar and beaver (Paaver 1965, 437 f.). The presence of wild horse (*Equus ferus*), brown bear (*Ursus arctos*), wildcat (*Felis silvestris*), several mustelids (Mustelidae) and European pond turtle (*Emys orbicularis*) suggests that the site was formed around the Atlantic climatic optimum. Fish bones come from freshwater species: pike and wels catfish dominate, with bream (*Abramis brama*) and perch represented by only single bones (Lõugas 1997, 25; Paaver & Lõugas 2003, 40). Soil sieving was not applied at excavation and therefore only 'big fish' were recorded, though the original range of caught fish must have been far more diverse. In terms of good preservation and taxonomic diversity the faunal assemblage at Kääpa is unique in Estonia.

### Settlement sites on shores of big inland lakes

Two large lakes existed in what is today Estonia in the Stone Age periods – Peipsi in the eastern and Võrtsjärv in the central part. Stone Age settlement sites are found on both shores, especially abundant on the shores of ancient Lake Võrtsjärv (Kriiska & Tvauri 2007, 21, 57), but Narva stage material is known at only one site – Kalmaküla.

### *Kalmaküla*

The settlement site at Kalmaküla in eastern Estonia is situated some hundred metres from Lake Peipsi, the biggest lake in Estonia. The site was discovered in 2008, but no excavations have been undertaken so far. Sherds of Narva-type pottery were collected in the course of surface survey. The sherds resemble the pottery assemblage of Riigiküla: fabric containing organic inclusions are represented. No animal bones have been found so far. The palaeogeographical situation still needs refinement, but it is nevertheless highly likely that the site was located on the shore of a big lake and is thus different from the other settlement sites discussed in this paper.

## Narva pottery chronology and lipid analysis of Kääpa sherds

Chronological frames for the Narva-type pottery in the northern part of the distribution area is provided by the previously obtained thirty-four radiocarbon dates from Estonian and Ingermanland (north-western Russia) settlement sites (Tables 1, 3). Dates from charcoal (13 samples), presumably without significant reservoir effect, are between 6023 ± 95 to 5268 ± 58 radiocarbon years, calibrated averaged ca 5000–4100 cal BC. Adding dates from burnt bones of terrestrial mammals (7 samples), which are probably as reliable, gives the currently oldest date from Izvoz 2 of 6212 ± 48 radiocarbon years (averaged ca 5200 cal BC), and the youngest (burnt fox bone from Kuzemkino 1) of 5090 ± 40 radiocarbon years (averaged ca 3900 cal BC) (Fig. 7). Kuzemkino date is also confirmed by shore displacement chronology (computer program Ranta-ajoitus Eesti 0-7700BP ver. 1.2a (6.4.04) (Jussila & Kriiska 2004a; primary data Jussila & Kriiska 2004b).

Most intriguing from the dates we have so far is the oldest date of Narva-type pottery in Estonia (ca 5500 cal BC) obtained from carbonized organic remains on potsherd found from Kääpa dwelling site. However, recent work has exemplified the relevance of considering a threat of reservoir effect and the importance of identifying substances analysed when dating pottery food crusts (Fischer & Heinemeier 2003; Hartz et al. 2012; Philippsen 2013; Philippsen & Meadows 2014). Thus, it was necessary to reconsider previous food crust dates from Kääpa and test the potential of reservoir offset at the site.

To re-examine the previously published AMS dates from the Narva pottery food crusts in Estonia we carried out lipid analysis of the food crusts from Kääpa sherds already AMS dated and yielding one of the earliest dates for Narva pottery in Estonia (Piezonka 2008). The aim was to identify substances in the vessels in order to check the reliability of these AMS dates (possible reservoir effect) and its influence on the chronological estimation of Narva stage pottery in Estonia. In addition to that we combined further lipid residue analysis and AMS dating of pottery food crust and related plant substances from Kääpa to determine the local reservoir effect (see below).

Organic residue analysis has been used in archaeology for several decades (for general overview see Evershed et al. 2001; Evershed et al. 2008; in Estonia, for example Vahur et al. 2011). In the case of sufficient preservation, this method helps to determine different biological substances absorbed into or deposited on ancient artefacts. Currently, GC-MS (gas chromatography-mass spectrometry) and GC-C-IRMS (gas chromatography-combustion-isotope ratio mass spectrometry) are the most widely used methods used to characterize the archaeological organic residues. Sometimes also bulk EA-IRMS, used to determine the isotopic fraction of bulk elemental carbon and nitrogen of the charred deposit, has been employed as a screening technique and additional source of information for identifying the origin of the organic substance. On the basis of the structure and distribution of different biomolecules, including the determination of their isotope ratios, one can connect the preserved biomolecular data with its provenance and differentiate e.g. plant, terrestrial and aquatic organisms. The latter become particularly important for further chronological estimations of specific substances due to inherit carbon reservoir effects in aquatic environments.

Two samples of food crust from the previously AMS dated and published Kääpa sherds (Piezonka 2008) were analysed by GC-MS and GC-C-IRMS. One of them (AI 4245: 2039) was earlier dated to 4990–4780 cal BC (KIA 33921, 5985 ± 35), the other (AI 4245: 2008) to 5620–5380 cal BC (KIA 35897, 6540 ± 40 BP) (Piezonka 2008; Table 1). To identify the substances dated we analysed 1 g of sherds and 20 mg of food crusts with acid extraction method and sample preparation protocol based on Craig et al. 2013. Additionally, bulk EA-IRMS analysis of food crust was conducted on 1 mg food crust samples at the Geology Department at the University of Tartu, without any pre-treatment.

Unfortunately, the preservation of lipids in the food crust sample from sherd 4245: 2008 is extremely poor and does not allow any further identification (see Table 2). However, the bulk IRMS results show rather depleted $\delta^{13}C$ and relatively

**Table 2.** Results of lipid residue analysis, AMS-dated Kääpa sherds

| Sherd (Kääpa AI 4245) | Sample type | Lipid preservation | APAA | Isoprenoids | GC-C-IRMS analysis | | Bulk EA-IRMS | | Interpretation | Radiocarbon lab. cod |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | $\delta^{13}C$ $C_{16:0}$ | $\delta^{13}C$ $C_{18:0}$ | $\delta^{13}C$ | $\delta^{15}N$ | | |
| : 2039 | Food crust | Good | $C_{16}$, $C_{18}$, $C_{20}$ | phy, TMTD | –35.14 | –35.16 | –29.77 | 11.32 | Aquatic | KIA-33921 |
| : 2039 | Ceramic matrix | Very good | $C_{16}$, $C_{18}$, $C_{20}$ | phy, TMTD | –33.78 | –32.97 | N/A | N/A | Aquatic | N/A |
| : 2057 | Food crust | Low | $C_{16?}$, $C_{18}$ | phy | – | – | –25.83 | 6.73 | Aquatic?/ animal? | N/A |
| | | | | | | | –26.01 | 8.22 | | KIA-51081 |
| : 2057 | Ceramic matrix | Low | x | x | – | – | N/A | N/A | | N/A |
| : 2008 | Food cust | Very low | x | x | – | – | –29.56 | 10.53 | Aquatic | KIA-35897 |
| : 1800 | Food cust | Good | $C_{16}$, $C_{18}$, $C_{20}$ | phy, TMTD | – | – | –32.09 | 9.05 | Aquatic | KIA-51077 |

high $\delta^{15}N$ values (–29.56 and 10.53 per mil respectively), which is consistent with a freshwater fish origin (see e.g. Heron et al. 2015).

The results of the lipid analysis from sherd 4245: 2039 are clearly indicative of degraded aquatic products (Table 2; Fig. 5). We managed to identify aquatic biomarkers in the lipids coming from its food crust as well as in the lipids absorbed into the ceramic matrix. Both ω-(o-alkylphenyl) alkanoic acids, with carbon atoms ranging from $C_{18}$ to $C_{20}$ and with trace amounts of the $C_{22}$ component, and isoprenoid fatty acids (phytanic and 4,8,12–trimethyltridecanoic acids) were evident. These ω-(o-alkylphenyl) alkanoic acids are typically derived from prolonged heating of the polyunsaturated fatty acids present in aquatic resources (molluscs, fish and aquatic mammals). This interpretation is also supported by the presence of isoprenoid fatty acids which are also high in aquatic oils. Hansel et al. (2004) associate these compounds with the processing of marine lipids. However, the same fatty acids have been attributed to the river or lake fish as well (Craig et al. 2007, 144 and literature cited). Finally, the GC-C-IRMS analysis for food crust and ceramic samples showed that the $\delta^{13}C$ values of the $C_{16:0}$ and $C_{18:0}$ acids were –35.1 and –35.2 for food crust and –33.8 and –33.0 for ceramic samples, which match typical values of freshwater resources (Craig et al. 2011; Cramp et al. 2014). Bulk IRMS results also support the aquatic origin of the food crust. Therefore, it is likely that the previously published two dates (at least one for certain) from Piezonka 2008 from Kääpa food crusts are influenced by freshwater reservoir effects and only provide maximum ages for these sherds.

To address the issue of freshwater reservoir effect, further combined lipid residue and AMS analysis was carried out with food crusts from Kääpa. Two sherds with food crust and directly associated terrestrial plant remains, which ought to be free from freshwater reservoir effect, were studied in depth. A sherd 4245: 2057 was deposited into archaeological collections together with an oblong piece of wood, curved exactly in the shape of the sherd as if seated into the surface

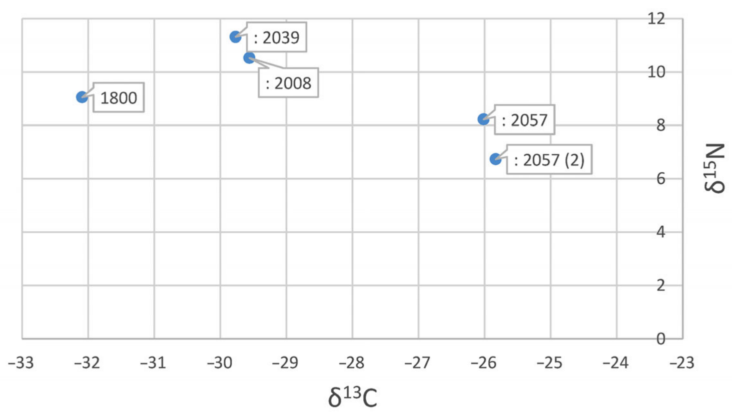


**Fig. 5.** Bulk IRMS analysis results of the AMS dated Kääpa food crusts.

of the vessel like an inner lining. The placement of these two objects indicates that they were in direct contact and either deposited together or belonging to very close subsequent depositional phase. The second pair of samples was taken from the sherd 4245: 1800 which has a plant fibre running through its repair hole (Fig. 6). This pair must be almost exactly from the same use phase.

The lipid analysis of the food crust of 4245: 2057, in this case, was not entirely conclusive (Table 2). We identified $C_{18:0}$ ω-(o-alkylphenyl) alkanoic acids, which may be derived from plants or aquatic resources, as well as phytanic acid (from ruminant or aquatic) and cholesterol derivatives (from animal). EA-IRMS was conducted on two samples, the bulk IRMS results of a subsample of food crust and the remains of the crust used for dating. The results show that these samples are more enriched in $^{13}C$ and more depleted $^{15}N$ values than the other three samples attributed to aquatic origin (see Fig. 5). Thus, combining the results of these chemical analyses, it seems that both terrestrial omnivores and/or low trophic level aquatic animals could be considered for the origin of this crust. The dating results (see below Table 3) gives support to at least some aquatic derived carbon in the crust.

In contrast, the food crust from the sherd 4245: 1800, is clearly of aquatic origin (Table 2) as attested by the presence of $C_{16:0}$, $C_{18:0}$, $C_{20:0}$ ω-(o-alkylphenyl) alkanoic acids, phytanic and 4,8,12-trimethyltridecanoic acids, and supported by the bulk IRMS results (Fig. 5).

The AMS dates obtained at the Leibniz Laboratory for Radiometric Dating and Stable Isotope Research at the Christian-Albrechts-University of Kiel from both pairs of samples give evidence of freshwater reservoir effect (Tables 1 and 3; Fig. 7). The offset between the dates from plant remains and food crust is 362 ± 42 (4245: 1800) and 486 ± 60 (4245: 2057) radiocarbon years, with the food crusts being consistently older.

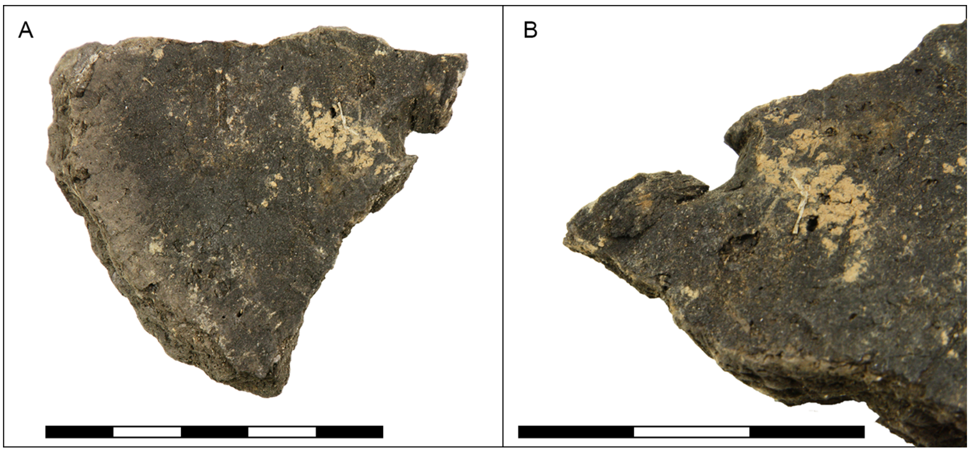


**Fig. 6.** General view (A) and close-up (B) of the dated plant fibre in situ in the repair hole of the Kääpa sherd (AI 4245: 1800). Photos by Ester Oras, technical realization Kristel Roog.

**Table 3.** New AMS dates from Kääpa food crusts and plant remains

| Sample | Material | Yield | AMS $\delta^{13}C$ (‰) | Conventional $^{14}C$ Age | Calibrated Date (95% probability) |
|---|---|---|---|---|---|
| KIA-51075 AI 4245: 1800 plant fibre | Burnt plant fibre, from repair hole | 40% C, 2.4 mg C | –32.48 ± 0.14 | 5910 ± 29BP | 4850–4710 cal BC |
| KIA-51076 AI 4245: 1800 food crust | Food crust, interior surface | 39% C, 2.3 mg C | –30.59 ± 0.17 | 6285 ± 51BP | 5320–5210 cal BC (calibration of weighted mean, 6272 ± 30BP) |
| KIA-51077 AI 4245: 1800 food crust | Food crust, exterior surface | 34% C, 1.9 mg C | –28.41 ± 0.13 | 6266 ± 36BP | |
| KIA-51079 AI 4245: 2057 wood | Wood, cross-section | 40% C, 2.8 mg C | –28.90 ± 0.11 | 5671 ± 29BP | 4590–4440 cal BC |
| KIA-51081 AI 4245: 2057 food crust | Food crust, exterior surface | 46% C, 2.3 mg C | –25.90 ± 0.16 | 6157 ± 53BP | 5230–4940 cal BC (94.3%) |

As these new AMS dates exemplify, it is of utmost importance to know the origin of the carbon in dated food crusts. Based on lipid analysis of previously dated sherds at least the one with sufficient preservation (sherd 4245: 2039) dated to 4990–4780 cal BC (KIA 33921) is most likely not reliable and potentially includes a reservoir offset. Although the same cannot be entirely ascertained for the other earlier sample (4245: 2008) due to its generally poor lipid preservation, its bulk IRMS data seems to suggest aquatic origin substances of food crust as well and thus freshwater reservoir effect cannot be excluded. The same freshwater reservoir effect is discernible in our new comparative lipid residue and AMS analysis of related plant remains and food crusts for sherds 4245: 1800 and 4245: 2057.

However, it is also necessary to keep in mind that the identification of lipids in food crusts does not directly correlate with the carbon dated in those crusts. Carbon analysed in AMS dating does not derive from lipids only, but can also come from other macronutrients, with low lipid contents (i.e. proteins and carbohydrates). Thus, bulk IRMS which analyses all the carbon in the food crust has been preferred as a good preliminary and faster, but also more quantitative screening method for AMS dating. Still, as the comparison of EA-IRMS results and dates obtained from the same sample (Piezonka et al. 2016) show, carbon and nitrogen isotopes only provide a very crude indicator of aquatic products, and these data and the degree of reservoir effect may vary considerably depending on the source(s) of aquatic carbon.

In contrast, lipids provide a more robust method for identifying aquatic products and should be widely deployed for additional screening of food crusts prior to AMS dating. In the case of this current pilot comparative lipid residue and AMS

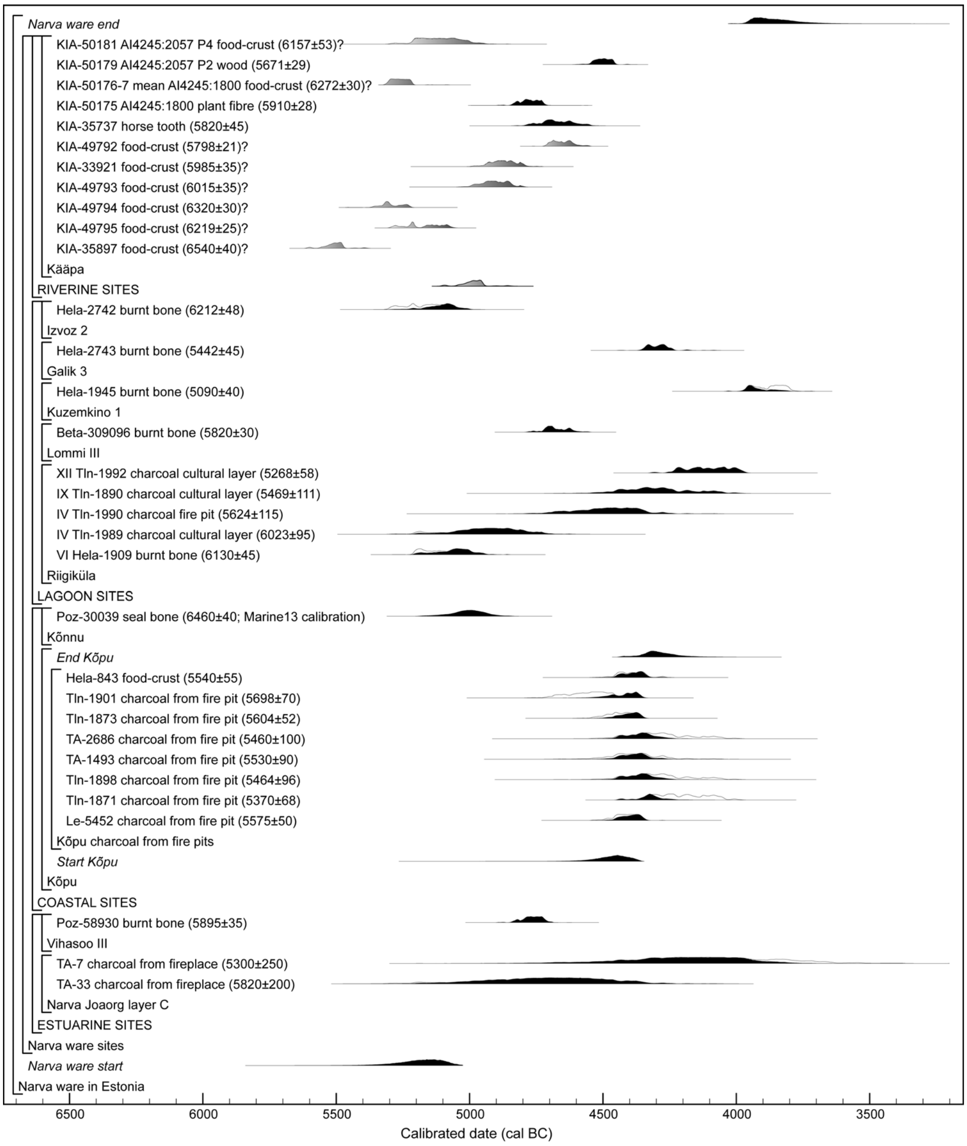


**Fig. 7.** Calibration of radiocarbon results from sites with Narva-type pottery (Tables 1 and 3). All results were calibrated using OxCal v4.2 (Bronk Ramsey 2009; 2013) and the IntCal13 atmospheric calibration curve (Reimer et al. 2013), except for the date from an unburnt seal bone, Poz-30039, which was calibrated using the Marine13 calibration model (Reimer et al. 2013) without local Delta-R correction, as it is difficult to estimate an appropriate value for the mid-Holocene Baltic. All the calibrated dates, except those from food crust samples at Kääpa (grey), have been included in a Bayesian simple bounded-phase model (Bronk Ramsey 2009), which estimates the dates of the beginning and end of the Narva-ware period in Estonia (distributions Narva ware start and Narva ware end), based on the scatter of calibrated radiocarbon dates (distributions in outline). This model incorporates a Bayesian bounded-phase model for the site of Kõpu, which provides posterior density estimates for the calibrated dates of this series of samples (solid distributions), given the scatter of calibrated dates (outline distributions).

study, the multi-analytical lipid analysis combining bulk isotopic data, biomarker based analysis and single compound isotopic fraction study has proven to be one useful possibility to estimate if the samples have higher potential for reservoir effects, which is important when considering dating food crusts.

## Discussion

This research exemplifies the diversity of the earliest pottery users, their subsistence ways and inhabitation environments in Estonia. We see contemporaneous, but very different settlement types covering a variety of environmental and geographical contexts from open coastal (Kõnnu and Lommi III), inland (Kääpa and Kalmaküla) to lagoon (Riigiküla IV and VI) and river estuary sites (Narva Joaorg and Vihasooo III). Settlement types also range from seasonal camps to sedentary dwellings, the latter typical of broad periods from the Late Mesolithic to Early Neolithic or even further (e.g. Narva Joaorg, Kääpa, some Riigiküla sites). As indicated by the general archaeological material, including faunal remains, the subsistence economy at these sites varied accordingly. In terms of identifying Narva stage subsistence economies there are some crucial aspects to be considered before drawing further conclusions. The faunal remains at the Narva sites are dominated by mammals. We see clearly distinct marine-oriented subsistence (primarily seal hunting) in the west Estonian islands and terrestrial subsistence in inland (elk, red deer, aurochs, wild boar, beaver and wild horse hunting) while Narva–Luga lagoon area is a kind of mixed economy where both terrestrial and marine mammals are hunted.

In contrast, fish bones are limited both numerically and in terms of species composition. However, here one has to take into account taphonomic processes and loss of smaller-sized material over time. The recovery and recording of tiny fish remains is also extremely dependent on excavation techniques, and particularly earlier excavations failed in finding and collecting all the fish bones. Thus, our current knowledge about life- and food-ways of Narva pottery people (especially when relying on older excavation results) is somewhat biased.

The first results of our lipid residue analysis suggest that aquatic resources were more important during the Narva-stage in Estonia. The residues detected in four Kääpa vessels are of aquatic origin. Although these initial results are not representative enough to draw any further conclusions, they provide the first indication regarding specialization in the use of early pottery, i.e. that vessels were used for storing and processing aquatic products, even though ruminant fats were widely available and perhaps even of greater overall dietary significance (see Oras et al. 2017). It has been suggested previously that in the eastern Baltic region, pottery was adopted as a practical aid for fish processing, besides storing seal blubber and other animal products (e.g. Núñez 1990, 38 and the literature cited). Future residue analysis studies offer the opportunity to test this hypothesis.

Despite considerable variations in Narva period inhabitation environments, settlement site types and subsistence practices, there is one common denominator – pottery. The Narva-type vessels are found from the 6th and extend to early 4th millennium BC in northern part of its distribution, thereby defining this particular period for archaeologists. Establishing a robust chronology – through direct and reliable dates – of this particular pottery type is very important for understanding the origins and development of the Narva phenomenon in the context of Baltic prehistory.

In relation to the latter, a very important implication, derived from the lipid analysis, is that the utilization of aquatic resources causes a reservoir effect that must be considered when dating food crusts. The problem of marine and freshwater reservoir effect derived from more depleted values of $^{14}C$ in water due to inclusion of old carbon (from fossil carbonate and deep ocean water) has been acknowledged for several decades (Stuiver & Braziunas 1993; in archaeology see e.g. Taylor et al. 1996, 657 f.; Lanting & van der Plicht 1998). Old carbon is incorporated into organisms living and feeding in those environments. This creates a substantial offset between dating results and real age, the first of which can be older by several centuries in the case of marine and even thousands of years in the case of freshwater organisms. To make matters worse, the freshwater reservoir effect varies considerably in spatial and temporal terms, as well as between and within species, depending on local ecology and specific diet of organisms (Keaveney & Reimer 2012; Philippsen & Heinemeier 2013). The issue of aquatic reservoir effect has been tackled in dating human bones by incorporating dietary studies which indicate the proportion of aquatic food in human diet and thus might explain, in good cases even correct, dating discrepancies (e.g. Lanting & van der Plicht 1998; Arneborg et al. 1999; Eriksson 2004; Fischer et al. 2007; Olsen et al. 2010; Piezonka et al. 2013). However, the same problems may apply to dating food crusts as well: when aquatic ingredients have been stored or cooked in vessels, food crusts and lipids absorbed in potsherds are also subject to possible reservoir effect (Fischer & Heinemeier 2003; Hartz et al. 2012; Philippsen 2013; Philippsen & Meadows 2014). These problems with dating pottery food crust have been recently acknowledged in the eastern Baltic archaeology (Pesonen et al. 2012; Zhulnikov et al. 2012; Piličiauskas & Heron 2015). For these reasons, the measurement of carbon and nitrogen stable isotope ratios ($\delta^{13}C$ and $\delta^{15}N$) in dated material is crucial, as aquatic organisms often have different isotopic signatures to terrestrial species.

In Estonia a freshwater reservoir effect has been demonstrated in some later contexts. For example, food crust on the sherds found in a fire pit of a Comb Ware complex (4000–1800 cal BC) site at Riigiküla II is about 350 radiocarbon years older than charcoal collected from the same pit.[2]

[2] Food crust on the Comb Ware sherd (TÜ 1507: 191) – 5220 ± 50 PB (Hela-1863) and charcoal (TÜ 1507: 248) from same fire pit – 4872 ± 38 PB (Hela-3256).

The small-scale test analysis of the previously dated Kääpa sherds proves the importance of and the necessity for identifying food crusts prior to dating. In the case of aquatic resources – which certainly is the case with one of the Kääpa sherds – the marine and especially freshwater reservoir offset can give misleading dates making the pots considerably older. In our study the effect is evident from two separate pieces of information: a) in the dates of the Kääpa site where wild horse bone yielded a result on average 400–1000 years younger than the AMS dates of the burnt organics in pottery (see Table 1); b) from the combined analysis covering both food crust lipid identification and dating of both crusts and directly related plant remains from the same sherds. Therefore, for future research the determination of lipid components has to become an intrinsic part of direct pottery dating and selecting suitable dating material in the first place. The result of our pilot of combined lipid and AMS analysis allows to state that the direct and earliest dates at least from the Kääpa Narva stage sherds belong to the early to mid-5th millennium cal BC and previously proposed early 5th to even mid-6th millennium BC must be taken with considerable precaution.

## Conclusions

1. The Narva-stage settlement sites epitomize five characteristic locations of dwelling and camp sites in Estonia and Ingermanland: 1) coastal river estuaries (Vihasoo III and Narva Joaorg in this article); 2) coast (Kõnnu and Kõpu IA); 3) coastal lagoons (Riigküla IV and VI and Lommi III); 4) inland river banks (Kääpa); 5) shores of larger inland lakes (Kalmaküla).
2. Faunal remains collected from dwelling sites exemplify differences in subsistence systems of Narva pottery people – 1) marine in the western Estonian islands, 2) terrestrial at inland sites, and 3) mixed subsistence in coastal lagoons area. However, these differences between pottery use and the wider economy evident from the faunal remains may indicate culturally mediated culinary practices and the selective use of foods in pottery in particular.
3. The available radiocarbon dates demonstrate that the differences between settlement and subsistence types are regional and not chronological. Based on reliable dating results (from charcoal or calcinated bones) Narva type pottery and therefore the Narva period in Estonia and Ingermanland (north-western Russia) dates to the period of 5200–3900 cal BC (Fig. 7).
4. As exemplified by our case study from Kääpa it is of utmost importance to identify the substances being dated when using AMS dates of food crusts through lipid residue analysis because the latter informs us about possible reservoir effect which can heavily modify our chronological estimations.

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## HILISMESOLIITILINE NARVA ETAPP EESTIS: SAVINÕUD, ASUSTUSTÜÜBID JA KRONOLOOGIA

*Resümee*

Läänemere piirkonnas levis savinõude valmistamise oskus 6. aastatuhande teisel poolel ja 5. aastatuhande algul eKr (joon 1). Ida-Baltikumis eristatakse tavaliselt kaht varajast keraamikatüüpi: Narva ja Dubičiai (varem Neemeni) tüüp, mille kasutuselevõttu on seletatud üldiselt kultuurilaenuna. Narva tüüpi keraamika nime alla on koondatud savinõude valmistamise traditsioon, mis oli levinud Eestis, Lätis, Leedus, Loode-Venemaal ja Valgevenes. Samas eristatakse selles mitmeid lokaalvariante või stiile (joon 4), mille olemasolu on põhjendatud kas välismõjutuse suuna või lokaalsete erijoontega, mis eksisteerisid juba enne keraamika kasutuselevõttu.

Narva tüüpi savinõud valmistati enamasti kitsastest savilintidest. Vormilt olid need terava või ümara põhja ja sirge või nõrgalt profileeritud seintega potid ning ovaalsed või ümarad kausid (joon 2, 3). Vormimismassi lisandina kasutati teokarpide purdu, peenestatud taimset massi, harvem ka kivipurdu ja liiva. Narva keraamika ornament erines mõnevõrra piirkonniti. Rohkem ja variatsioonide-rikkamalt kaunistati nõusid Lätis ning Kagu-Eestis, kõige vähem dekoreeriti savipotte Lääne-Eesti saartel. Keraamikat kasutati nii säilitamisanumatena kui ka keedunõudena.

Narva keraamika leviala põhjapoolses osas, Eestis ja Ingerimaal, on nii asustustes kui ka majanduses mitmeid erinevusi. Elukohtade paiknemise järgi saab eristada viit asustustüüpi: 1) rannikujõgede estuaarid (käesolevas artiklis käsitletud asulakohtadest Vihasoo III ja Narva Joaorg), 2) avamere rand (Kõnnu ja Kõpu IA), 3) ranniku laguunid (Riigküla IV ja VI ning Lommi III), 4) sisemaa jõgede kaldad (Kääpa), 5) sisemaa järvede kaldad (Kalmaküla). Asulakohtadest kogutud looma- ja kalaluud osutavad kolmele püügimajanduse eritüübile: 1) mereline majandus (hülgeküttimine) Lääne-Eesti saartel, 2) maismaaline majandus (metsloomade jaht

ja kalastamine siseveekogudel) sisemaal, 3) segamajandus (nii mere- kui ka maismaaloomade jaht ja kalastus) rannikulaguunides. Samas näitavad esmased Narva tüüpi savinõude pinnal säilinud toidujäänustest tehtud lipiidide uuringud kalapüügi suuremat tähtsust, kui seda võiks asulakohtadest kogutud arheozooloogilise ainese põhjal järeldada.

$^{14}$C dateeringud Eestist ja Ingerimaalt (tabel 1, 3, joon 7) osutavad, et Narva keraamikat valmistati selle tüübi leviala põhjaosas ajavahemikus 5200 (Izvoz 2) kuni 3900 aastat eKr (Kuzemkino 1). Senine vanim dateering Kääpa asulakohast leitud savinõukillu kõrbekihist – ligikaudu 5500 eKr – on tõenäoliselt reservuaariefektiga ja nõu tegelikust valmistusajast vanem.

Selle kontrollimiseks uuriti Kääpa keraamikakildudest kombineeritud gaasikromatograaf-massispektromeetri (GC-MS), gaasikromatograafpõletiga stabiilsete isotoopide massispektromeetri (GC-C-IRMS) ja stabiilsete isotoopide massispektromeetri (EA-IRMS) abil lipiidijääke. Tulemused osutavad kõrbekihi pärinemisele kaladelt, mistõttu võib oletada mageveelise reservuaariefekti olemasolu selles materjalis (joon 5).

Võrdlev dateerimine, mille käigus määrati AMS-meetodil nii Kääpa savinõukildude pinnale jäänud toidujäätmete kui ka taimejäänuste vanus (joon 6), osutas, et kõrbekiht võib reservuaariefekti tõttu anda Kääpas isegi kuni 500 radiosüsinikuaastat vanema aja kui taimejäänused. Saadud tulemused osutavad selgelt vajadusele kaasata lipiidide uuringuid mitte ainult savinõude funktsiooni kindlakstegemisel, vaid ka keraamika dateerimisel ja võimaliku reservuaariefekti hindamisel.

Artiklis on näidatud, et nii keraamika tunnuste, asustuse kui ka majandusviisi poolest on Narva etapp Eesti ja Ingerimaa aladel küllaltki varieeruv ning seda võiks ajaliselt piiritleda ajavahemikuga 5200–3900 eKr (joon 7).