GLOBULAR AMPHORA CULTURE POTTERY IN THE EASTERN BALTIC: NEW SITES, VESSEL CONTENTS AND CHRONOLOGY

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ABSTRACT

Until now, Šventoji in north-west Lithuania was considered the most northerly site of the Neolithic Globular Amphora Culture (hereafter GAC; ca. 3400-2500 cal BC) in Europe. Recently, however, ceramics typologically resembling GAC ware were identified among the materials from the multi-period sites of Abora 1 and Iča in Latvia, and further to the north from Tamula in south-east Estonia. In this contribution we present the multi-disciplinary analyses of these ceramics, including their form, function and chronology to ascertain whether they could represent sporadic migrations of GAC groups into the region or exchange and increasing social contacts with the indigenous hunter-gatherers during the period from ca. 3000-2600 cal BC. Overall, our results align with previous studies showing that GAC groups in the Eastern Baltic possibly reorientated their economy from animal husbandry towards fishing as recently evidenced from the composition of zooarchaeological assemblages, and the organic residue analysis of ceramic vessels, which markedly differ to the GAC communities of Central Europe. Indeed, in several coastal and southern regions of Lithuania it would appear that some GAC migrants replaced the indigenous Subneolithic[1] forager groups, whilst in other areas they had little to no impact on the local cultural and economic development.

INTRODUCTION

The Globular Amphora Culture (GAC) is the youngest (ca. 3400-2500 cal BC) of the Neolithic cultures in Central Europe that are genetically linked to Anatolian farmers (Szmyt 2001; Woidich 2014; Mathieson et al. 2018; Tassi et al. 2017; Schroeder et al. 2019). It preceded, and was partly synchronous with the Corded Ware Culture (hereafter CWC) that

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[1]In this contribution the Subneolithic (ca. 5500/5000-2900/2800 cal BC) and Neolithic (ca. 2900/2800-1800 cal BC) periods are marked by the presence of pottery and domesticated animals respectively.

was distributed throughout Europe, which dates from ca. 2900/2800-2400/2200 cal BC (e.g. Müller 1999; Lanting & Van der Plicht 1990-2000; Hübner 2005; Ebbesen 2006; Włodarczak 2006; Larsson 2009; Piličiauskas 2018; Kriiska & Nordqvist 2021). The CWC is largely associated with migrants from the Eurasian steppe located to the south-east (Haak et al. 2015; Saag et al. 2017). Since both of these cultures had no local roots in the Eastern Baltic, their appearance has largely been explained as the result of Neolithic pastoralists migrating from Central Europe to the north (Loze 1979; Szmyt 1996a; Rimantienė 1984; 2002; Brazaitis 2002; Kriiska & Nordqvist 2021). Whilst some (e.g. Lang 1998) have explained this marked cultural change was a result of an internal cultural development, this interpretation has largely been refuted. Recently, ancient DNA (hereafter aDNA) analysis of CWC individuals from the Eastern Baltic as well as those of the Fatyanovo culture, a local variant of the CWC in north-west Russia, has demonstrated that they are characterised by a mixture of steppe-related and Anatolian Neolithic farmer ancestry. Indeed, these analyses have shown that both of these cultural groups are genetically similar to the CWC peoples from Central Europe as opposed to local hunter-gatherers (Haak et al. 2015; Jones et al. 2017; Mittnik et al. 2018; Saag et al. 2017; 2021).

In contrast, aDNA analysis of GAC individuals from the Eastern Baltic has not yet been undertaken due to the lack of human remains from the period. Despite this, a migration-based scenario similar to that of the CWC also seems plausible for the GAC given the dispersal of material culture, especially ceramics, in the north and east (Fig. 1). This likely event took place several hundred years after the beginning of the GAC in Central Europe (Szmyt 1996a), and was accompanied by profound typological changes in lithics in the area occupied by the Rzucewo Culture (hereafter RC) (Rimantienė 1989; Saltsman 2004). Indeed, the earliest phase of the RC has been recognised as being derived from a GAC tradition (Saltsman 2013; Piličiauskas & Heron 2015), whilst syncretic pottery traditions combining GAC ware traits with those of the local hunter-gatherers' wares did not evolve (Piličiauskas 2018). aDNA analysis of GAC individuals from Poland and Ukraine has demonstrated that they are characterised by a mixture of Western European hunter-gatherer and Anatolian Neolithic farmer ancestry (Tassi et al. 2017; Mathieson et al. 2018; Schroeder et al. 2019). Based on these data, it is plausible that both the GAC and CWC dispersed into the Southeastern Baltic as genetically diverse populations and through human migration rather than social contacts between Central European farmers and indigenous hunter-gatherers in the Southeastern

Baltic.

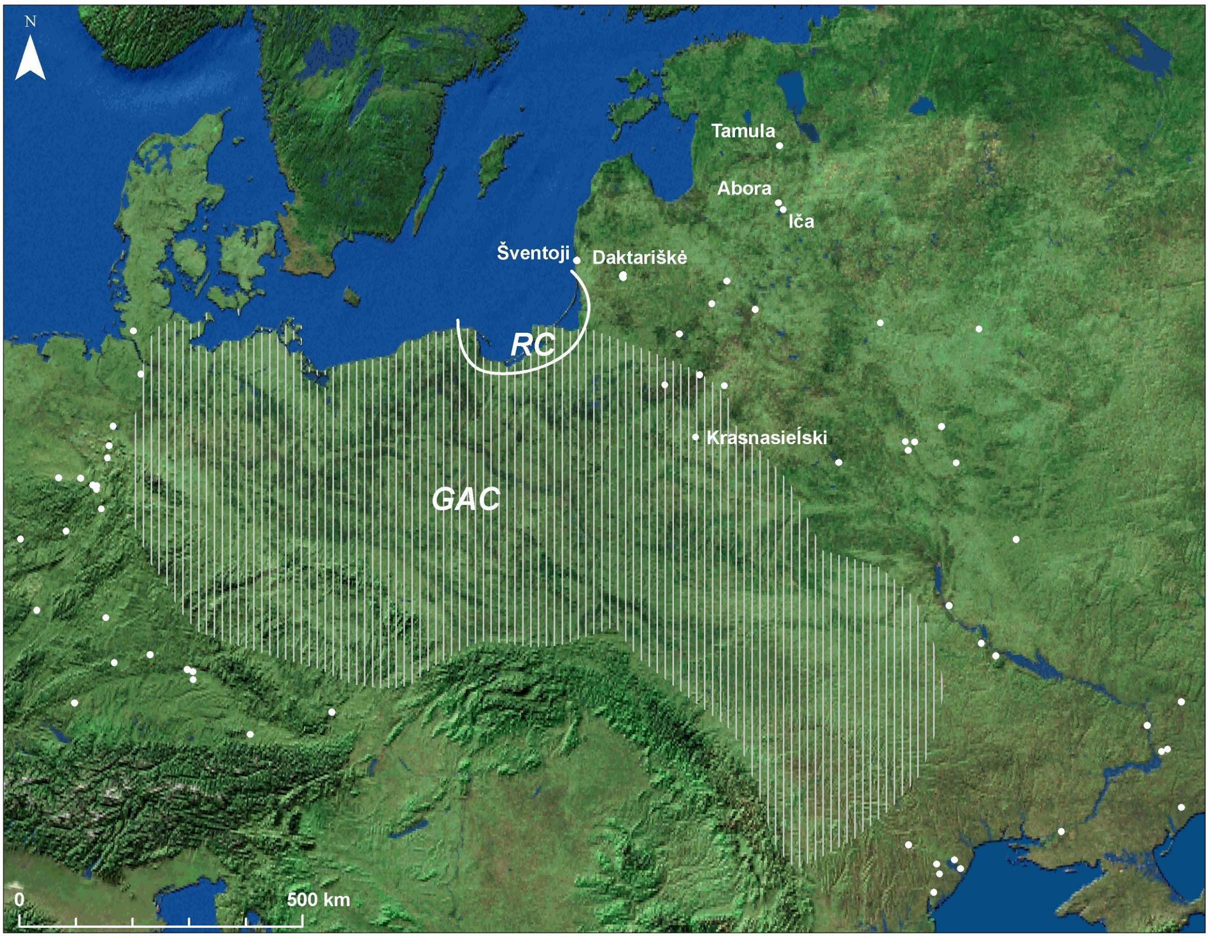

Fig. 1. The Globular Amphora culture throughout Europe at ca. 3400-2500 cal BC, including the studied sites. The main area of the culture is highlighted while distant sites are marked by dots. RC - Rzucewo Culture (after Woidich 2014, 1f. with additions).

Until recently, the sites of Šventoji 2/4 and 6 in north-western Lithuania were considered the most northerly GAC sites within Europe (Szmyt 1996a; Rimantienė 2005). However, in 2017 potsherds, very similar in appearance to GAC ware from Lithuania, were identified amongst the ceramic assemblages of three Estonian and Latvian multi-period sites, i.e. Tamula, Abora and Ilča (Fig. 1). Little is currently known about the origin, function and chronology of GAC ceramics at such northern latitudes. To rectify this imbalance somewhat, here we typologically examined the GAC pottery from the three sites; performed organic residue analysis, including elemental analysis-isotope ratio mass spectrometry (EA-IRMS) of partially carbonised surface deposits (hereafter foodcrusts), and gas chromatography-mass spectrometry (GC-MS) followed by GC-combustion-isotope ratio MS (GC-C-IRMS) on a subset of ceramic vessels from Tamula; report the AMS radiocarbon (^{14}C) dates of a GAC cattle burial from KrasnasieĺÍski (Belarus) and two foodcrusts adhering to GAC potsherds from Tamula and Daktariškė 5 (Lithuania) as well as the bones of two fish, including a modern white bream (*Blicca bjoerkna*) from the River Virvytė, an outflow of Lake Biržulis, and an archaeological common bream (*Abramis brama*) from Daktariškė 5, situated on the same lake, to estimate the local freshwater reservoir effect. In light of these analyses, we discuss pottery typology, function and chronology of these GAC materials but also try to address their likely origin in the Eastern Baltic.

SITES

To date, around 20 habitation sites, fisheries and presumed human burials, including material traits of GAC, are known in the Eastern Baltic (Table 1). Contrasting with the GAC enclaves of Central Europe, it has a very low concentration of sites. For instance, as of 1996 more than 1000 GAC sites were known from the Kujawy region of Poland alone (Szmyt 1996b). In comparison with Central Europe, where GAC human burials are numerous and easily recognisable due to specific stone constructions as well as grave goods, notably the GAC ceramics that were interred with the deceased (Wiślański 1966; Szmyt 1996b), clear evidence of GAC human burials in the Eastern Baltic is lacking. In addition, there is a clear difference in the number of sites between the GAC and CWC in the Eastern Baltic. For example, ca. 80 CWC habitation sites and human burials are known from Lithuania compared with the 19 GAC sites (Piličiauskas 2018). Despite these marked differences between the two cultures, the number of recovered potsherds per site between the two cultures are somewhat comparable. In general, and regardless of the size of the excavated area, one or two vessels are often present, whilst there are only a handful of sites where a dozen or more vessels have been recovered. Similarly, three GAC vessels were recovered from three sites respectively, in northern Belarus (Čarniaŭski & Vajtovič 2019).

No.	Site name	Country	Site type	Environment	MNV
1	Šventoji 1	Lithuania	Refuse layer	Lagoon	55
2	Šventoji 2/4	Lithuania	Refuse layer	Lagoon	43
3	Daktariškė 5	Lithuania	Refuse layer	Lake	32

4	Šventoji 6	Lithuania	Refuse layer (dwelling area?)	Lagoon	12
5	Tamula	Estonia	Dwelling area with burials	Lake	8
6	Katros ištakos 1	Lithuania	Dwelling area	Lake	7
7	Daktariškė 1	Lithuania	Dwelling area	Lake	5
8	Jara 2	Lithuania	Dwelling area (burial?)	Lake	5
9	Dubičiai 1	Lithuania	Dwelling area	Lake	4
10	Gribaša 4	Lithuania	Burial?	Lake	2
11	Ića	Latvia	Dwelling area	Lake	2
12	Kulnikas	Lithuania	Dwelling area	Lake	2
13	Šventoji 28	Lithuania	Dwelling area	Lagoon	2
14	Abora 1	Latvia	Dwelling area	Lake	1
15	Jakšiškis	Lithuania	Burial?	River	1
16	Katra 1 (?)	Lithuania	Dwelling area	River	1
17	Kretuonas 1	Lithuania	Dwelling area	Lake	1
18	Merkinė environs (?)	Lithuania	Unknown	Unknown	1
19	Mitriškės	Lithuania	Unknown	River	1
20	Petrašiūnai (?)	Lithuania	Unknown	River	1
21	Skirmantinė 1	Lithuania	Dwelling area	Lake	1
22	Zapsė 5	Lithuania	Dwelling area	Lake	1

Table 1. GAC sites in the Eastern Baltic with the estimated Minimum Number of Vessels (MNV) attributed to the GAC. Question marks denote those sites in which the typological classification of ceramics was problematic due to a scarceness of material.

In the Eastern Baltic, the majority of GAC sites are located in Lithuania (Fig. 1). However, some of the sites listed in Table 1 cannot be securely assigned due to the presence of very small potsherds (i.e. potsherds smaller than <5 cm) or very small assemblages (i.e. 1-2 potsherds per site). Alternatively, other forms of material culture have been more forthcoming, such as polished flint axes, often represented by stray finds. Previously, a separate GAC enclave was proposed in south-west Lithuania due to the higher concentration of polished flint axes there (Piličiauskas 2007), however, since they could not be distinguished from those of the CWC on typological grounds, coupled with the lack of settlement sites in the region (Brazaitis & Piličiauskas 2005), the hypotheses could not be proven. More detailed descriptions of the studied sites are provided below.

KRASNASIEĹSKI, BELARUS

Krasnasieĺski is a GAC burial ground that is located in the Upper Neman basin, western Belarus. It was discovered due to chalk exploitation and investigated in 1971. Four rectangular pits containing animal bones, GAC vessels and other forms of material culture were excavated. The best preserved pit, No. 3, measured 4 m in length and 2 m in width, and included a mass animal burial. The remains of 13 animals represented by nine cattle (*Bos taurus*), two sheep/goat (*Ovis* sp./*Aries* sp.), one pig (*Sus* sp.), and one horse (*Equus* sp.) were found (Fig. 2). Four GAC ceramic vessels, two bone needle-shaped spearheads, and a piece of amber were interred with the animal remains, but no human remains were found. The burial has been identified as a ritual deposit. It is not clear, however, if the other three pits (presumably burials) at the site had been used for human burial as they were badly damaged by a mechanised excavator. It has been suggested that GAC people were attracted to Krasnasieĺski because of the rich chalk flint outcrops present, which appear to have been extensively mined throughout the course of the Neolithic (Charniauski 1996). Burial No. 3 yielded a radiocarbon age of 4080 ± 140 BP (Gd-9249) (Kadrow & Szmyt 1996).

TAMULA, ESTONIA

A Neolithic settlement and burial ground was investigated on the shore of Lake Tamula in 1938, 1942-1943, 1946, 1955-1956, 1961, 1968 and 1988-1989 (Fig. 1). Altogether an area of 657 m^2 was excavated (Jaanits 1984; Kriiska et al. 2007; Tõrv 2019). The majority of finds were recovered from a Subneolithic-Neolithic lakeshore settlement, whilst 25 burials were also excavated from the cultural layer. Due to a rise of the water level the cultural layer was covered by peat, which preserved bone, antler and wood. Among the ceramic materials, Comb Ware vessels predominated while ceramics with cord impressions, previously attributed to the CWC, were less numerous. Twenty one dates obtained on human remains and various artefacts from the occupation layer date the site from ca. 3900-2600 cal BC when a significant correction for the freshwater reservoir effect was applied (Tõrv 2019).

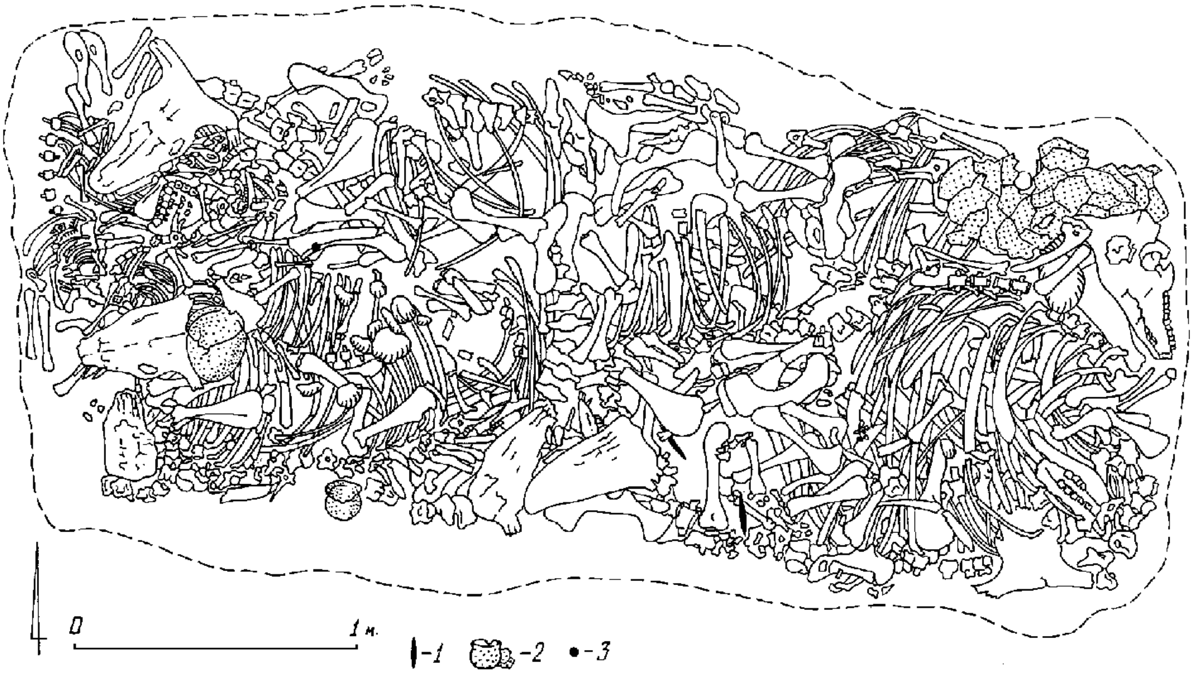

Fig. 2. Plan of burial No. 3 at Krasnasieĺski in western Belarus, including find locations. 1 - bone spearhead, 2 - pottery, 3 - amber (drawing by Mikhail Charniauski (1996), reproduced with permission from Maxim Charniauski).

ABORA 1, LATVIA

Abora 1 is situated near Lake Lubāns in Latvia (Fig. 1). Between 1964-1965, 1970-1971, and in 2008 an area of 1,313.5 m^2 was excavated by Ilze Loze (1979; Loze & Eberhards 2015). Numerous Neolithic finds, including wooden artefacts and bones, as well as settlement structures, including post holes and fireplaces were uncovered. Sixty-one burials were also excavated within and under the cultural layer (Loze 1979). Among the pottery inventory, shell-tempered flat-bottomed Neolithic Porous Ware vessels predominated, followed by Corded Ware ceramics (Piličiauskas et al. 2020). The site dates from ca. 2940-2470 cal BC (Loze & Eberhards 2015).

IČA, LATVIA

Iča is another Subneolithic-Neolithic site in the Lake Lubāns basin in Latvia (Fig. 1). It was investigated in 1988 and 1989. Numerous stone, antler and amber artefacts were recovered from an excavated area of 506 m^2. Subneolithic/Neolithic Porous Ware and Neolithic Corded Ware vessels as well as Early Bronze Age Lubāns Ware ceramics were identified. The site dates from ca. 3320-2570 cal BC (Loze 2000).

DAKTARIŠKĖ 5, LITHUANIA

Daktariškė 5 is situated in western Lithuania in the Lake Biržulis basin (Fig. 1). The site was excavated between 1987 and 1990 as well as 2016. During the earlier excavation campaigns an area of 648 m^2 was investigated. Over 11,000 potsherds, 326 lithics, a number of bone and antler artefacts, wooden poles and fishing floats were found alongside stone net sinkers, and 132 amber artefacts and flakes (Butrimas 1992; Butrimas & Ostrauskienė 2004). In 2016 two more trenches were excavated measuring 24.0 and 24.6 m^2 respectively (Piličiauskas 2018). The site was situated in the littoral zone of an ancient lake. The archaeological layer at the shoreline was very thin and unstratified whilst further into the lake a stratified layer was identified. The ceramics were attributed to the Subneolithic Porous Ware, Early Neolithic Globular Amphora Ware and Corded Ware as well as the Late Neolithic and Early Bronze Age Post-Corded Ware (Piličiauskas et al. 2020). The site dates from ca. 4450-1600 cal BC, which is based on 40 radiocarbon dates (Piličiauskas 2018).

ŠVENTOJI 2/4, LITHUANIA

Šventoji 2/4 is situated in the north-western region of Lithuania (Fig. 1). A total of 3,253 m^2 have been excavated by various researchers in 1967, 1969, 1972, 1986-1995, 1997-1998, 2002-2006, and 2014 (Juodagalvis & Simpson 2000; Rimantienė 2005; Piličiauskas 2016a; 2016b). Subneolithic and Neolithic finds include the numerous remains of fishing gear as well as freshwater fish remains that were found within the waterlogged gyttja of the former lagoonal lake. The uppermost horizon, A1 (ca. 2720/2650-2700/2620 cal BC), was several centimetres thick and contained at least 43 GAC vessels. The lower horizons, A2 (ca. 2800/2720-2720/2650 cal BC) and B (ca. 3110/3000-3020/2930), contained Subneolithic Porous Ware vessels. The site was situated in the deepest part of the lagoonal lake and continued to be used as a fishery almost until the lake was overgrown at ca. 2400 cal BC.

METHODS

EXAMINATION OF POTTERY

Pottery assemblages, held in museums in Estonia, Latvia and Lithuania, were visually examined to ascertain a number of attributes, including technology and style. Attributes, characteristic to the Eastern Baltic GAC pottery variant were taken from the Lithuanian sites of Šventoji 1, 2/4, 6 and Daktariškė 5, which have yielded the largest GAC ceramic assemblages through the region (Rimantienė 2005; Piličiauskas 2018). They are illustrated in Figures 4-6 and discussed in the Results: *Pottery* section. To estimate the minimum number of vessels, individually shaped and/or ornamented potsherds from the upper parts of vessels were counted.

RADIOCARBON (^{14}C) DATING

Radiocarbon (^{14}C) dating of the foodcrusts (n = 2) and bones (n = 3) was undertaken at the Poznań Radiocarbon Laboratory (Poland) and the Mass Spectrometry Laboratory, Centre for Physical Sciences and Technology, Vilnius (Lithuania). In Poznań, collagen extraction was performed using the procedures originally described by Longin (1971) with further modifications (Piotrowska & Goslar 2002). The extracted collagen was ultrafiltered using pre-cleaned Vivaspin™ 15 kDa MWCO filters (Brown et al. 1988; Bronk Ramsey et al. 2004). In Vilnius, prior to graphitisation, the bone samples were pre-treated using an acid-base-acid (ABA) followed by gelatinisation (Szidat et al. 2017). In this study all radiocarbon ages were calibrated using the OxCal 4.2 software and IntCal13 atmospheric curve (Bronk Ramsey 2009; Reimer et al. 2020). Calibrated dates are presented at 95.4% probability.

STABLE ISOTOPE ANALYSIS OF BONE COLLAGEN

Carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) stable isotope analysis of bone collagen was undertaken on 3 bone samples at the Institute of Geological Sciences, PAS, Warsaw (Poland), and the Centre for Physical Sciences and Technology, Vilnius (Lithuania). The $\delta^{13}C$ and $\delta^{15}N$ values were obtained from the same collagen extract that had been directly dated by AMS. In Warsaw a Thermo Flash EA 1112HT Elemental Analyser connected to a Thermo Delta V Advantage Isotope Ratio Mass Spectrometer in continuous flow mode was used. In Vilnius, an Elemental Analyser Flash EA1112 linked to a Thermo V Advantage Mass Spectrometer was employed. Delta values were normalised to a calibration curve based on the following international standards, USGS 40, USGS 41 and IAEA 600. Overall, analytical uncertainties were <0.2 and <0.3‰ for $\delta^{13}C$ and $\delta^{15}N$ respectively.

STABLE ISOTOPE ANALYSIS OF FOODCRUSTS

Carbon (δ^{13}C) and nitrogen (δ^{15}N) stable isotope analysis of partially carbonised surface deposits adhering to ceramic vessels were measured at the Centre for Physical Sciences and Technology, Vilnius (Lithuania). The samples (n = 4) were removed directly from the interior surfaces of the potsherds using a scalpel, and then analysed in duplicate without any pretreatment by the same instrumentation described above. The values were averaged.

ORGANIC RESIDUE ANALYSIS OF CERAMICS

Organic residue analysis was undertaken on a subset of 10 GAC potsherds from the Estonian site of Tamula. In total, 12 samples were analysed which were represented by ceramic powder (*n* = 9) and partially carbonised surface deposits (*n* = 3) that had been removed from the interior surfaces of the potsherds. Two potsherds were sampled twice (AI 4118:1542 and AI 5861:294). Initially, the surfaces of the nine potsherds were removed to a depth of ca. 2 mm using a Dremel Drill fitted with a tungsten abrasive bit so as to reduce potential contamination from the burial environment. This powder was then disposed of. Approximately 1 g of the ceramic powder was then removed by drilling to a depth of ca. 4 mm from the potsherd surfaces. In comparison, the surface deposits were removed directly from the surfaces of the potsherds using a scalpel. All samples were homogenised using a mortar and pestle for acidified methanol extraction (Craig et al. 2013; Papakosta et al. 2015), which was followed by gas chromatography-mass spectrometry (GC-MS) and GC-combustion-isotope ratio MS (GC-C-IRMS) at the University of York (UK). The instrumentation employed was identical to previous studies (i.e. Robson et al. 2019; Piličiauskas et al. 2020).

RESULTS

POTTERY

GAC pottery was identified among the materials of three Estonian and Latvian sites: Tamula, Abora 1 and Iča. Until now these materials were attributed to the CWC despite the fact that they have very distinct technological and stylistic characteristics that are not typical for the CWC ceramics. Their closest analogies are with the GAC pottery tradition.

From Tamula in south-east Estonia, GAC potsherds from at least eight vessels, including amphorae, wide-mouthed pots and smaller vessels, were identified (Fig. 3). Although the main forms of CWC ceramics are beakers and short-wave moulded pots, both were absent in the Tamula assemblage. Coarse granite temper, used to manufacture the GAC vessels at Tamula, has not been identified in CWC pottery throughout the Eastern Baltic. The CWC potters usually used grog, sand and fine organics as temper (Kholkina 2017; Piličiauskas 2018). However, granite particles were clearly the dominant temper for making GAC vessels in Lithuania, Belarus and Poland, as well as RC ware, whose earliest phase is recognised as being linked to a GAC tradition (Saltsman 2013; Piličiauskas & Heron 2015). The surfaces of the Neolithic vessels from Tamula were smoothed (Fig. 3), similar to GAC ceramics from Lithuania (Fig. 4-6), and different to CWC vessels from the Eastern Baltic, which are represented by, for instance, short-waved moulded pots with striated surfaces (Szmyt 1996a; Brazaitis 2002; Rimantienė 2002; Čarniaŭski & Vajtovič 2019). The ornamentation of the GAC vessels from Tamula is also different to the CWC pottery tradition. The Tamula ceramics were decorated by horizontal cord impressions that were combined with deep pits (Figs. 3:1, 5, 8). Occasionally, bands of horizontal cord impressions were passed by vertical cord impressions (Figs. 3:2, 8) and sometimes zigzags made of cord impressions were formed (Fig. 3:7). Cord and pit designs are well known among GAC pottery from Lithuania while vertical cord-impressed zones as well as zigzags are frequently found on both GAC and RC pottery in the Eastern Baltic; all are, however, absent on CWC ceramics (Rimantienė 1989; 2005; Piličiauskas 2018). Moreover, at least a single vessel from Tamula possessed holeless lugs, which are common for the GAC tradition though absent on CWC vessels. And finally, flattened vessel edges are present in the Tamula vessels, and similar to other GAC pottery from Lithuania alongside round edges (Figs. 3-6), whilst flattened edges without an increase in thickness are absent in CWC vessels. To conclude, the closest typological analogies for the discussed Neolithic pottery at Tamula are GAC ceramics from modern day Lithuania (Figs. 4-6), whilst its difference to Estonian CWC pottery is clear (Fig. 7).

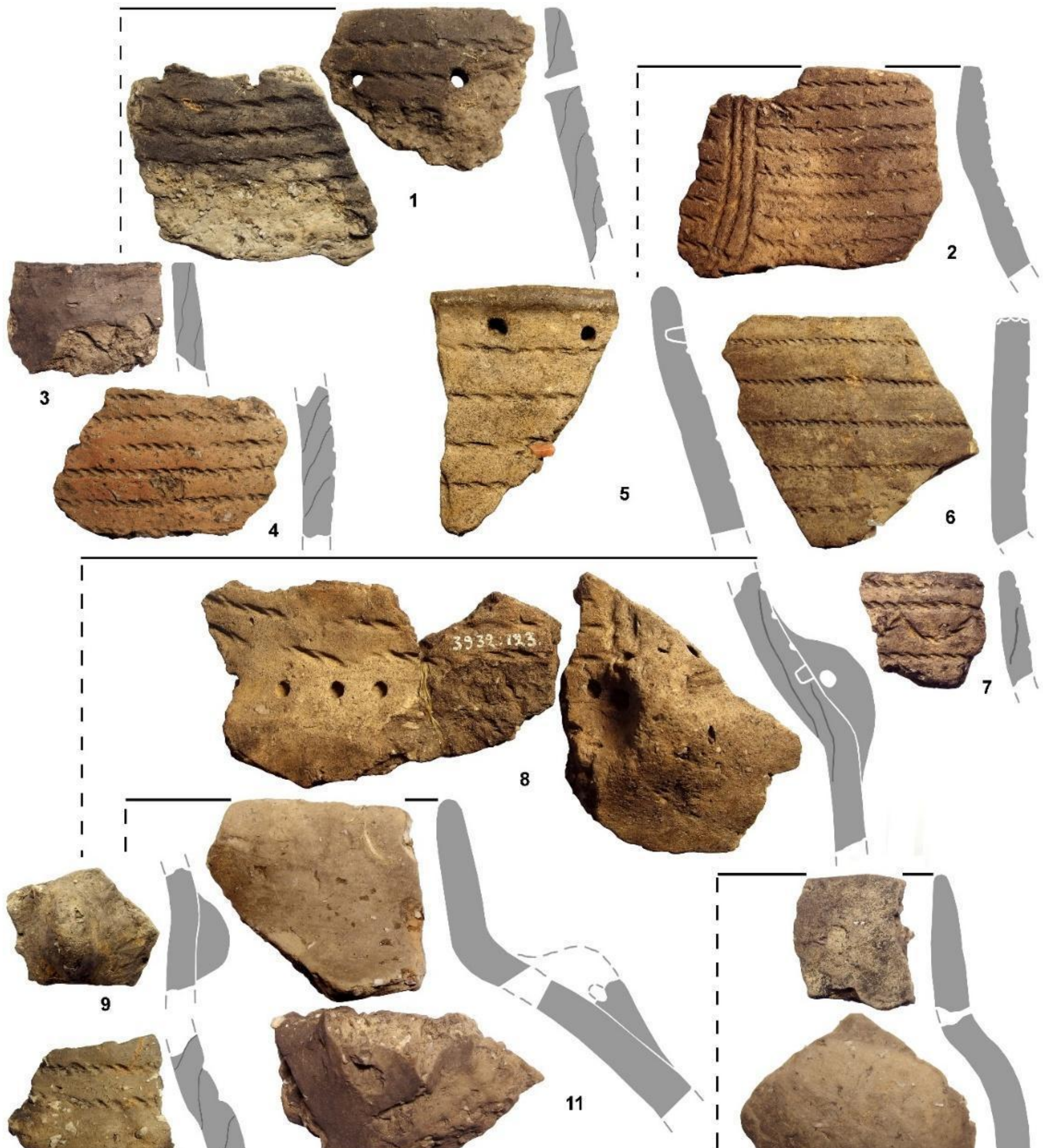

Fig. 3. GAC pottery from Tamula, south-east Estonia. Institute of History, Archaeology and Art History in Tallinn: 1 - 4118:1852+5861:175, 2 - 5861:264, 3 - 4118:1131, 4 - 4118:2024, 5 - 4118:1312, 6 - 5861:276, 7 - 4118:160, 8 - 3932:123+4118:1352, 9 - 3932:140, 10 - 4118:1873, 11 - 4118:3105+4118:2623, 12 - 4118:2614+4118:2699.

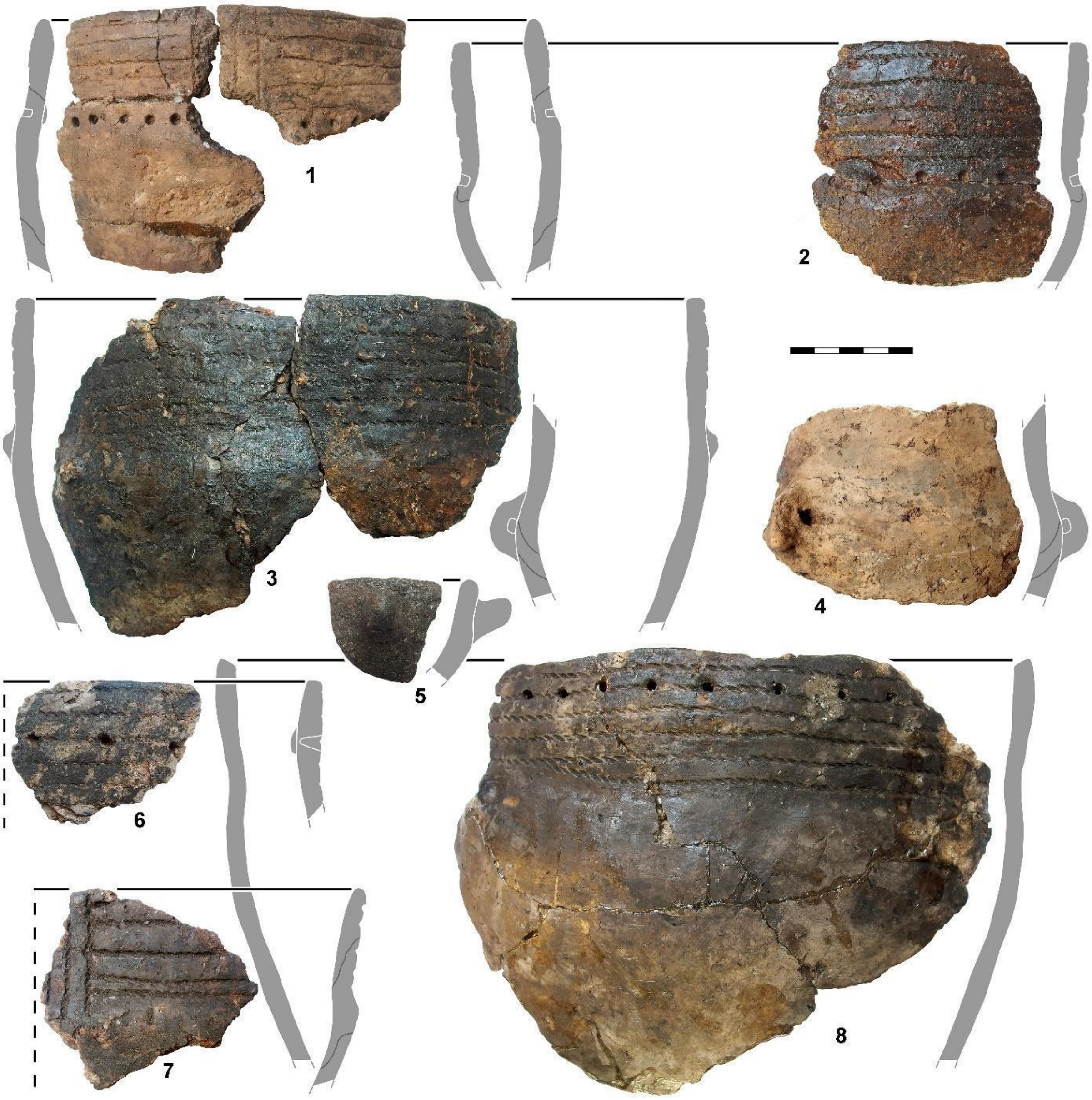

Fig. 4. GAC pottery from Šventoji 1, north-west Lithuania. National Museum of Lithuania: 1 - A1a+A13b, 2 - A10d, 3 - A8c+B7c, 4 - A15b, 5 - A33f, 6 - A7c2, 7 - A5c+A4c, 8 - A8ė.

Fig. 5. GAC pottery from Šventoji 2/4, north-west Lithuania. National Museum of Lithuania: 1 - Šv2 2/2a, 2 - Šv4 2003/1278, 3 - Šv2 2zA, 4 - Šv4 2002/591, 5 - Šv4 2006/EM2136:825, 6 - Šv 2002/1337, 7 - Šv4 2006/5325/1.

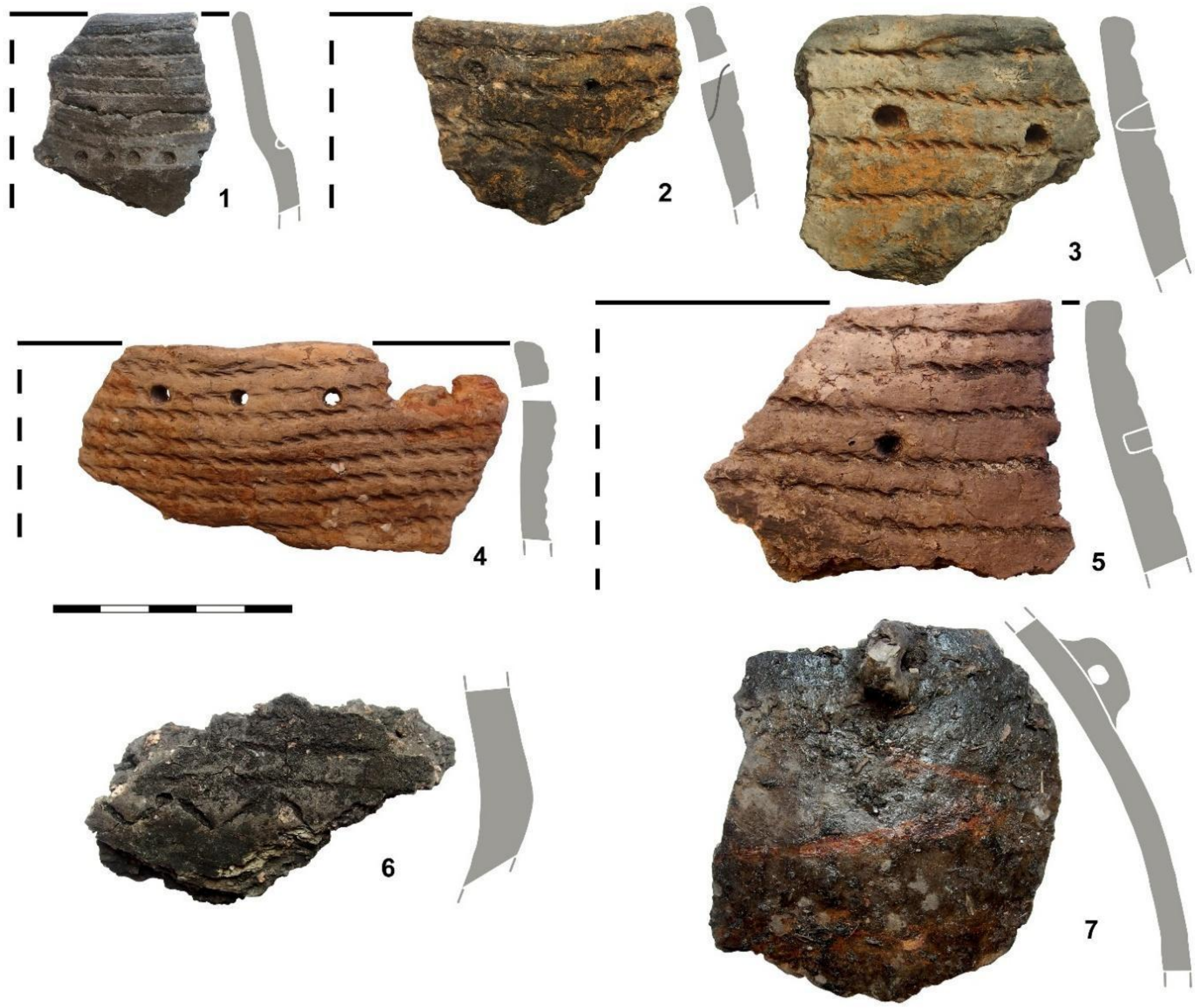

Fig. 6. GAC pottery from Daktariškė 5, western Lithuania. National Museum of Lithuania: 1 - VIII, 2 - X4b, 3 - III4a, 4 - III6b, 5 - V7a, 6 - without number, 7 - V6a1.

At Abora 1 in eastern Latvia only one GAC potsherd was identified (Fig. 8:1). However, the GAC potsherd differed to the other pottery types at the site: coarse granite temper and a holeless lug that had been attached to the neck of the vessel. At Iča, situated on the same lake as Abora 1, two further potsherds having GAC pottery elements were identified (Figs. 8:2-3). Coarse granite temper and a flattened rim indicate that these potsherds are probably GAC ceramics rather than CWC vessels. It seems that the potsherds belonged to a bowl and a wide-mouthed pot, which are common forms in the GAC pottery inventory of Lithuania (Figs. 4-6) and elsewhere.

Fig. 7. Selected CWC potsherds from Estonian sites, Tika (1), Valma (2-3), Võhma (4), Tamula (5), Sope (6). Institute of History, Archaeology and Art History in Tallinn: 1 - 3663:3, 2 - 4022:5479, 3 - 4022:119, 4 - 6395:36, 5 - 4118:1709, 6 - 3175:2.

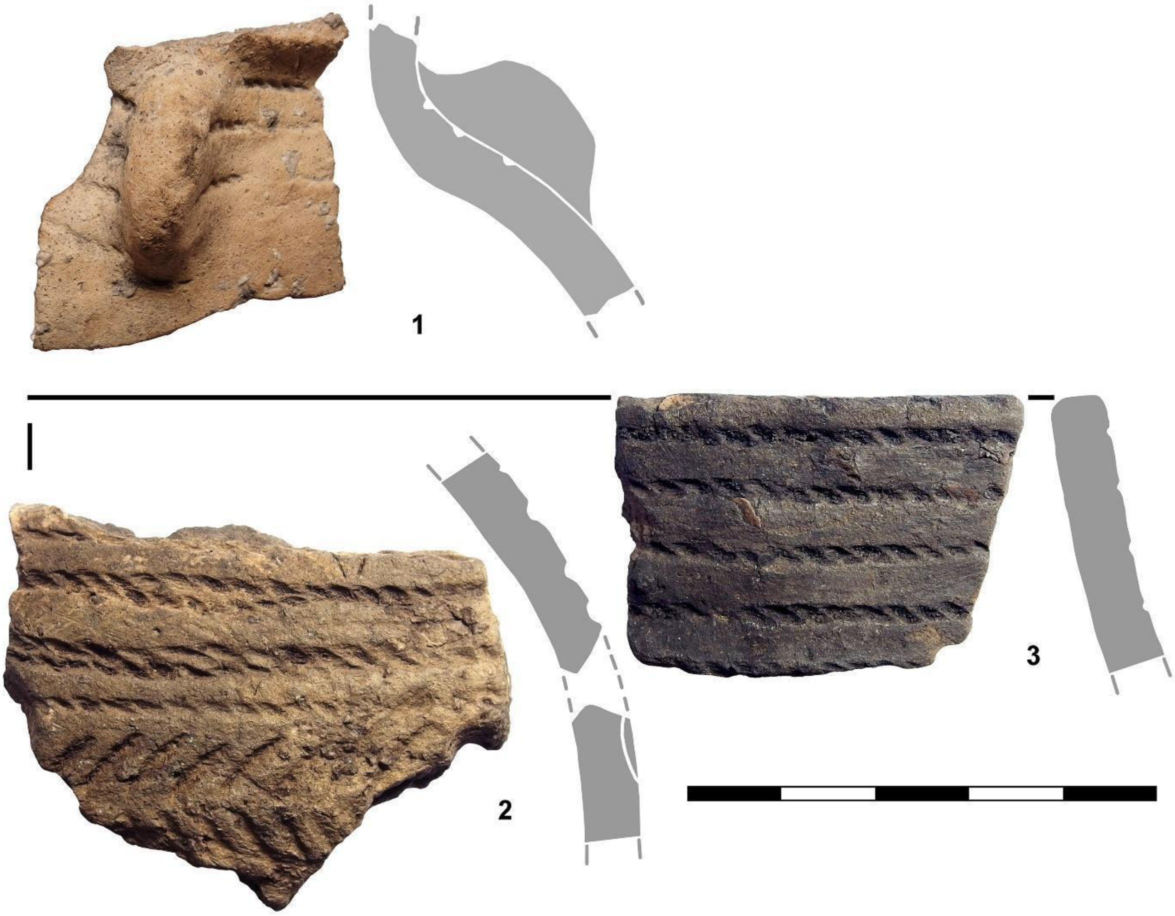

Fig. 8. GAC pottery from Abora 1 (1) and two potsherds with some GAC traits from Iča (2-3), eastern Latvia. National History Museum of Latvia in Rīga: 1 - 604, 2 - A10987:1(II), 3 - A10987:1.

It is difficult to interpret the presence of GAC vessels in the Lake Lubāns area of Latvia. They may have entered a Subneolithic or CWC settlement via exchange or may have been left during an episodic visit by GAC potters or larger groups in the area. In contrast, Tamula's GAC ceramic assemblage is larger and more varied. Potsherds from eight vessels belonging to three vessel types were recovered over several excavation campaigns (i.e. 1942, 1955, 1956, 1961, 1988 and 1989), and throughout much of the excavated area, ca. 50 x 15 m in size. Thus, it is hard to imagine that vessels with varying functions had been exchanged with the inhabitants at Tamula from GAC enclaves in Lithuania or Poland. Moreover, the ornamentation points to an alternative explanation being possible. A flattened rim of a single vessel was decorated by perpendicular cord impressions (Fig. 3:6). Whilst this decorative element is foreign in both the GAC and CWC pottery traditions of Lithuania, it has been frequently identified on Estonian CWC vessels (Piličiauskas 2018, Fig. 97:8; Kriiska &

Nordqvist 2021). Perpendicular cord impressions on a vessel's rim are also a common feature of Hybrid Ware pots, which is a syncretic pottery type that combines Subneolithic and Neolithic traits and is frequently found in north-eastern Lithuania (Piličiauskas 2018, Fig. 91). This type of rim decoration may originate from producers of Porous and/or Late Comb Ware ceramics. If the GAC vessels had reached modern day Estonia as trade items without their producers, we would have expected at least one or two types of high quality fine ware, e.g. amphorae without any local stylistic modifications, within the ceramic assemblage. However, this was clearly not the case in the Tamula pottery assemblage in which a range of locally made vessels, including amphorae, wide-mouthed pots and smaller vessels were used. Furthermore, stylistically local ornamentation on the vessel's edge was observed in one case. Overall, it seems that GAC people, or at least their potters, rather than their pots reached Tamula with the newcomers having potential contacts with the local Comb Ware or CWC people.

DIET AND VESSEL FUNCTION

In Central Europe, the GAC peoples were primarily animal herders (Szmyt 1996b). Indeed, the importance of domesticated animals to their economic and/or ideological spheres of life is attested by the numerous cattle burials dating to the period (Woidich 2014). However, neither human nor cattle burials are currently known from Estonia, Latvia or Lithuania. For instance, despite yielding the youngest radiocarbon ages of all dated individuals at the site of Tamula, two flexed burials (Nos. I and III) contained the remains of local foragers, and not those of presumed GAC or CWC migrants as evidenced by aDNA analysis (Mittnik et al. 2018).

In general, the lack of zooarchaeological remains from GAC habitation sites in the Eastern Baltic highly obscures our understanding of the subsistence practices and diet during this period. Moreover, the short period of site use, e.g. the stratified sites of Šventoji 2/4 and Daktariškė 5 in western Lithuania, often of the order of several decades, means that the formation of separate and distinctive horizons are absent. Although there are numerous multi-period sites with GAC materials on higher ground, bones are largely absent or could not be securely assigned to the GAC. In contrast, at the lacustrine site of Šventoji 2/4, which has good preservation for organic materials, including bone remains, domestic animal remains were completely absent - except for dogs (*Canis familiaris*) (Stančikaitė et al. 2009; Piličiauskas 2016b). Similarly at Tamula, where the archaeological layer contained mixed

Subneolithic and Neolithic materials, no animal bones of domestic species were identified (Tõrv 2019). During the Subneolithic period, fishing took place at Šventoji 2/4 as evidenced by the numerous remains of mainly freshwater fish that were found together with Porous Ware potsherds. Fishing appears to have continued at the site during the GAC though perhaps on a reduced scale judging from the lower frequency of their remains in the uppermost cultural horizon (Fig. 9). Alternatively, less fish were processed and consumed directly at the fishing station during the Neolithic.

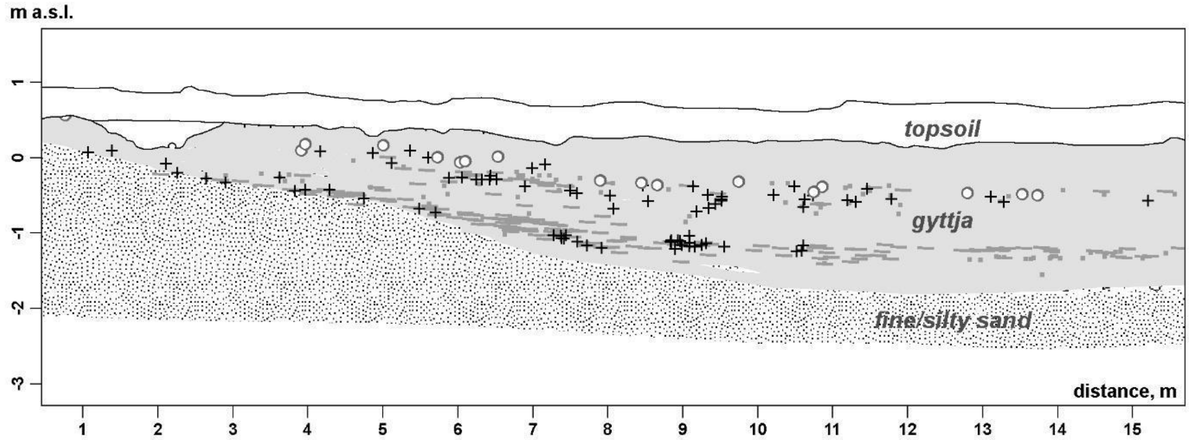

Fig. 9. Digitised section from the Šventoji 2/4 site, north-west Lithuania. Subneolithic Porous Ware potsherds are marked by crosses, GAC potsherds by circles, and fishbone concentrations by grey dashes. Excavations in 2014 by GP.

At another lacustrine site in Lithuania, Šventoji 1, potsherds from 55 GAC vessels were found alongside potsherds from 33 CWC vessels in the same upper horizon, A. Likewise, it was impossible to disaggregate the animal remains to culture securely (Rimantienė 2005; Piličiauskas 2018). Remains of only two domestic animals were identified from horizon 1A at Šventoji, cattle and sheep/goat (Stančikaitė et al. 2009), but it was impossible to assign them to the CWC or GAC.

Macrobotanical materials from Eastern Baltic GAC sites are even scarcer than the zooarchaeological evidence. The remains of hazelnuts (*Corylus avellana*) and burnt water chestnuts (*Trapa natans*) from the upper horizon at Šventoji 2/4, however, demonstrates that they were harvested and consumed during the GAC - perhaps in a similar manner to the preceding Subneolithic period.

Another source of dietary information pertaining to the GAC derives from the organic residue analysis of ceramics, including carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) stable isotope analysis of foodcrusts adhering to the interior walls of potsherds. This approach allows foodstuffs to be directly and unambiguously associated with ceramic phases, particularly important for assemblages where phases cannot be clearly distinguished. In this study a total of four foodcrusts adhering to GAC vessels from Tamula were analysed by EA-IRMS. The results are plotted alongside data obtained from additional GAC ceramics throughout Lithuania in Fig. 10, which were acquired during a previous study (Piličiauskas et al. 2018). Interestingly, the data from Tamula differ to the majority of the Lithuanian GAC data exhibiting higher $\delta^{15}N$ values ($\delta^{15}N$ = 10.3 ± 0.8‰; n = 4), and lower $\delta^{13}C$ values ($\delta^{13}C$ = -29.5 ± 1.5‰; n = 4). Overall, the Lithuanian GAC data ($\delta^{15}N$ = 8.4 ± 2.2‰; $\delta^{13}C$ = -27.0 ± 1.3‰; n = 53) are largely comparable (Fig. 11) with the data for the preceding Subneolithic period ($\delta^{15}N$ = 9.6 ± 2.1‰; $\delta^{13}C$ = -27.9 ± 1.5‰; n = 53) as well as the somewhat contemporaneous RC potsherds ($\delta^{15}N$ = 9.5 ± 1.3‰; $\delta^{13}C$ = -30.0 ± 1.7‰; n = 56), though different to the CWC ceramics ($\delta^{15}N$ = 5.6 ± 2.2‰; $\delta^{13}C$ = -26.7 ± 0.9‰; n = 58) (Piličiauskas et al. 2018; 2020; Robson et al. 2019).

Moreover, the CWC $\delta^{15}N$ values are noticeably lower compared with the data obtained from all of the Subneolithic and Neolithic cultures implying a shift from the processing of aquatic to terrestrial products in ceramics coincident with the beginning of a Neolithic economy throughout the south-eastern Baltic (Piličiauskas et al. 2018). This interpretation corresponds well with the zooarchaeological and human bone collagen stable isotope data which both imply that domestic animals were important dietary sources for the majority of CWC groups in the Eastern Baltic (Lõugas et al. 2007; Piličiauskas 2018; Kriiska & Nordqvist 2021). In contrast, the generally higher $\delta^{15}N$ values of the GAC vessels from Tamula indicate that the vessels had probably been used to process aquatic fats (see below) implying a degree of continuity from the Subneolithic period, which may indicate a possible reorientation of the economy from animal husbandry to fishing in some northern latitudes during the Neolithic as has been demonstrated elsewhere (see Piličiauskas et al. 2020).

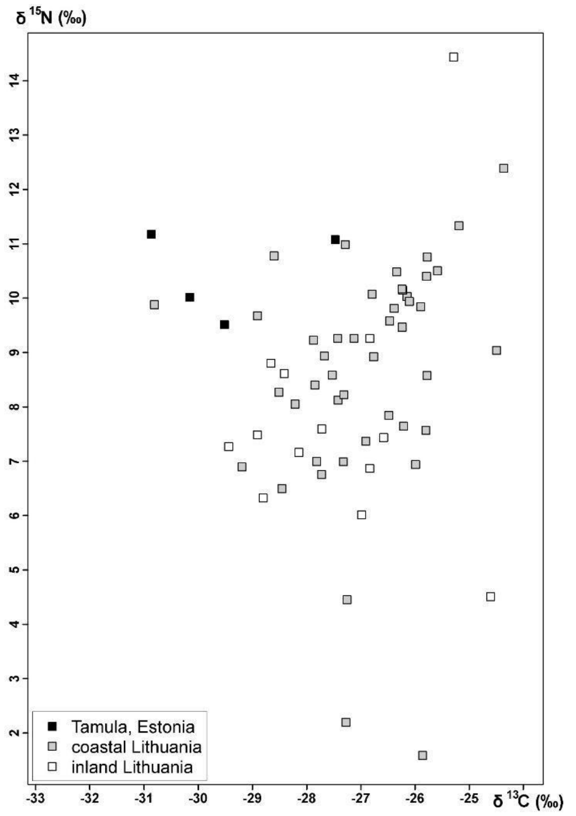

Fig. 10. Bulk $\delta^{13}C$ and $\delta^{15}N$ stable isotope data obtained from foodcrusts adhering to GAC potsherds from Tamula. The Tamula data are plotted against data previously obtained from GAC ceramics throughout Lithuania (Piličiauskas et al. 2018).

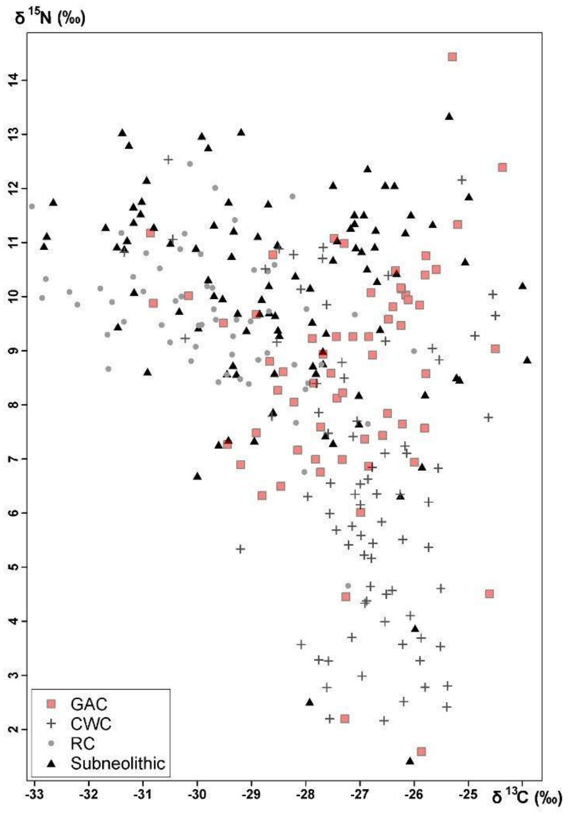

Fig. 11. Bulk $\delta^{13}C$ and $\delta^{15}N$ stable isotope data obtained from foodcrusts adhering to Subneolithic, RC, CWC and GAC ceramics (including Tamula) throughout the Eastern Baltic (data from Oras et al. 2017; Piličiauskas et al. 2018; 2020; Robson et al. 2019).

Compared to EA-IRMS, the molecular and isotopic characterisation of lipids trapped within the ceramic matrix or foodcrust provides a much higher resolution of vessel use (Evershed 1993; 2008; Evershed et al. 2001; Regert 2011). In this study 10 GAC potsherds, represented by ceramic powder (*n* = 9) and foodcrusts (*n* = 3) that had been removed from their interior surfaces, were sampled for acid extraction followed by gas chromatography-mass spectrometry (GC-MS) and GC-combustion-isotope ratio MS (GC-C-IRMS). Indeed, it was our intention to corroborate or contradict the stable isotope data which demonstrated that aquatic resources had likely been processed in the vessels. Of the 12 samples, the majority (*n* = 11) yielded sufficient quantities of lipids required for interpretation (i.e. > 5µg g^{-1} for ceramic powder and >100 µg g^{-1} for foodcrusts (Evershed 2008; Craig et al. 2013)), with lipid concentrations ranging from 21.2 to 325.9 µg g^{-1} (Table 2).

Corroborating the stable isotope data there was indeed evidence for the processing of aquatic fats (i.e. fish, aquatic birds, aquatic mammals and/or shellfish) in four different GAC vessels (Tm-5861:294, AI 5861:294, AI 5861:175 and AI 4118:1293) from Tamula (Table 2). Analysis by GC-MS revealed *ω*-(*o*-alkylphenyl)alkanoic acids (hereafter APAAs) with 16, 18 and/or 20 carbon atoms, which are formed during the heating of polyunsaturated fatty acids in the tissues of aquatic animals (Hansel et al. 2004; Cramp & Evershed 2014), together with at least one isoprenoid fatty acid (i.e. 4,8,12-trimethyltridecanoic acid, pristanic acid or phytanic acid). Moreover, these four vessels also had *SRR*% values (77.8, 74.8, 87.4 and 77.1% respectively), which were higher than the other sampled sherds (Table 2), whilst only one (i.e. 74.8%) was below the aquatic threshold (see Lucquin et al. 2016; Shoda et al. 2017). Given the broad range of the *SRR*% values (2.0 to 87.4%), multiple sources of fats, including mixtures of resources from aquatic and terrestrial environments, are likely to have been processed in the GAC vessels from Tamula.

Recently, however, the interpretation of APAAs with 20 carbon atoms in archaeological ceramics has been called into question (see Bondetti et al. 2021). Via a combination of field and laboratory experiments it has been demonstrated that APAA-C_{20} isomers are not exclusive to aquatic products, and can form in a range of products at varying temperatures. The study also indicated the use of the APAA C_{20}/C_{18} ratio for further separation between aquatic and terrestrial animals and plants (Bondetti et al. 2021). Despite these considerations, the four Tamula vessels with APAA-C_{20} isomers had APAA C_{20}/C_{18} ratios which were above the 'interim' threshold for terrestrial products (Table 2), confirming that aquatic resources were indeed the likely source of the lipids.

The results of the Estonian GAC sherds were similar with previous findings (see Heron et al. 2015; Robson et al. 2019). For instance, of the nine GAC vessels from the Lithuanian sites of Daktariškė 5, Gribaša 4 and Šventoji 2/4, five (55.6%) had been used to process aquatic fats. Moreover, plant products, beeswax and birch bark (*Betula* spp.) tar were identified, whilst the carbon (δ^{13}C) stable isotope values of mid-chain fatty acids (palmitic, $C_{16:0}$ and stearic, $C_{18:0}$ acid) demonstrated that non-ruminant adipose fats, and rarely ruminant adipose or dairy fats, had been processed (Heron et al. 2015; Robson et al. 2019). In contrast, the data differ somewhat to those reported by Roffet-Salque et al. (2017) and Weber et al. (2020) on the analysis of GAC vessels from the sites of Kierzkowo and Wangels LA 69, megaliths in Poland and Germany respectively (see below).

Carbon ($\delta^{13}C$) stable isotope values of mid-chain fatty acids (palmitic, $C_{16:0}$ and stearic, $C_{18:0}$ acid) were obtained from nine GAC vessels from Tamula (Table 2). These data are plotted alongside data obtained from 22 GAC vessels from the sites of Daktariškė 5 and Šventoji 2/4 (Heron et al. 2015; Robson et al. 2019) as well as Kierzkowo (Roffet-Salque et al. 2017) and Wangels LA 69 (Weber et al. 2020) in Fig. 12. Interestingly, all nine vessels from Tamula fell within the range established for freshwater fats (Figs. 12A & 12B) corroborating the aforementioned results. In comparison, only one vessel from Daktariškė 5 had been used to process ruminant dairy fats (i.e. butter, cheese, milk), whilst the remaining vessels from the site had been used to process either freshwater fats or a combination of freshwater and ruminant adipose fats. On the other hand, the three vessels from Šventoji 2/4 had been used to process freshwater fats (Heron et al. 2015; Robson et al. 2019), whilst the vessels from Kierzkowo had been solely used to process ruminant adipose and dairy fats (Roffet-Salque et al. 2017). The vessels from Wangels LA 69 exhibited more variation in their use, including the processing of ruminant adipose and dairy fats as well as plant products (Weber et al. 2020).

For further comparison, the carbon ($\delta^{13}C$) stable isotope values of mid-chain fatty acids (palmitic, $C_{16:0}$ and stearic, $C_{18:0}$ acid) obtained from GAC vessels are plotted alongside data obtained from CWC and RC vessels throughout the Eastern Baltic (Fig. 13). On the whole, the GAC vessels had been primarily used to process freshwater fats, whilst evidence for the processing of ruminant adipose and dairy fats is currently limited to only a handful of samples. Likewise, whilst the processing of freshwater fats features frequently in the use of the CWC vessels, there is considerable evidence that ruminant adipose and dairy fats as well as non-ruminant adipose fats (i.e. porcine and marine fats), and mixtures thereof had been processed (Cramp et al. 2014; Pääkkönen et al. 2019; Piličiauskas et al. 2018; 2020; Robson et al. 2019). In contrast, only two RC vessels from the site of Nida had been used to process ruminant dairy fats, whilst the majority had been used to process freshwater fats followed by ruminant adipose, porcine and marine fats as well as mixtures thereof. Perhaps the latter finding is not entirely surprising since the RC data are derived from two coastal sites, i.e.

Nida and Rzucewo (Heron et al. 2015; Cramp et al. 2019).

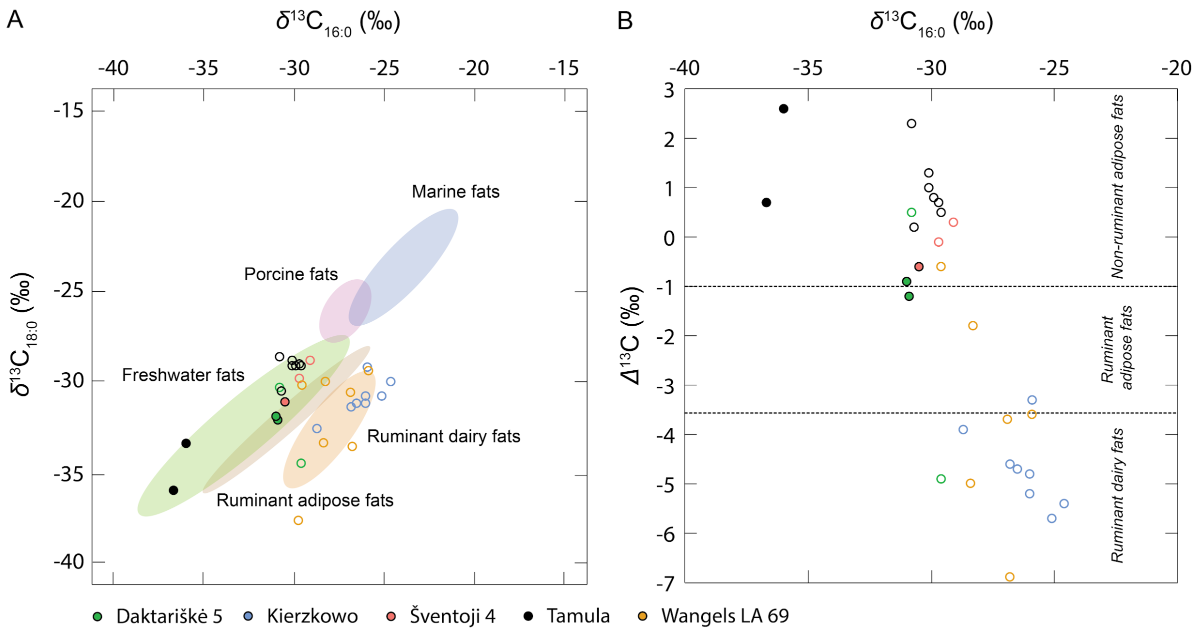

Fig. 12. A - $\delta^{13}C$ values of mid chain-length fatty acids ($C_{16:0}$ and $C_{18:0}$) extracted from GAC vessels from the sites of Daktariškė 5 (Robson et al. 2019), Kierzkowo (Roffet-Salque et al. 2017), Šventoji 2/4 (Heron et al. 2015; Robson et al. 2019), Tamula (this study) and Wangels LA 69 (Weber et al. 2020). B - Difference in the $\delta^{13}C$ isotope values ($\Delta^{13}C$) between the mid chain-length fatty acids ($C_{18:0}$ and $C_{16:0}$) extracted from the same samples plotted in (A). The reference ranges, calculated at 95% confidence, were derived from data obtained from the tissues of modern authentic animals throughout the Eastern Baltic (Dudd 1999; Courel et al. 2020; Pääkkönen et al. 2020). Closed circle - sample with aquatic biomarkers, open circle - sample without aquatic biomarkers. Note that one vessel from Wangels LA 69 is omitted from (B) as it yielded a $\Delta^{13}C$ value of -7.9‰ (Weber et al. 2020).

Overall, the data demonstrates that GAC pottery in the Eastern Baltic was primarily used to process aquatic fats from freshwater environments. Indeed, this practice may have been continued from the preceding Subneolithic foragers throughout the region. It is during the CWC when animal husbandry, including evidence for the processing of ruminant adipose and dairy fats in ceramics, becomes more widespread throughout the Eastern Baltic (Lõugas et al. 2007; Robson et al. 2019).

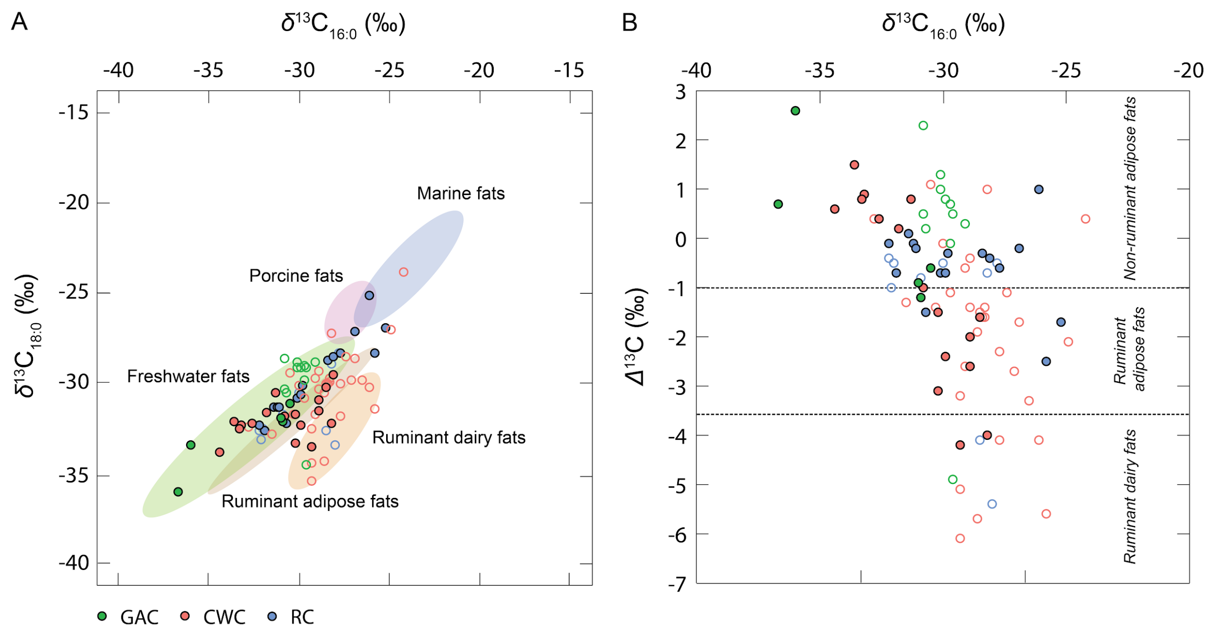

Fig. 13. A - $\delta^{13}C$ values of mid chain-length fatty acids ($C_{16:0}$ and $C_{18:0}$) extracted from GAC (Heron et al. 2015; Robson et al. 2019; this study), CWC (Cramp et al. 2014; Piličiauskas et al. 2018; 2020; Pääkkönen et al. 2019; Robson et al. 2019) and RC (Heron et al. 2015; Cramp et al. 2019) ceramics throughout the Eastern Baltic and adjoining regions. B - Difference in the $\delta^{13}C$ isotope values ($\Delta^{13}C$) between the mid chain-length fatty acids ($C_{18:0}$ and $C_{16:0}$) extracted from the same samples plotted in (A). The reference ranges, calculated at 95% confidence, were derived from data obtained from the tissues of modern authentic animals throughout the Eastern Baltic (Dudd 1999; Courel et al. 2020; Pääkkönen et al. 2020). Closed circle - sample with aquatic biomarkers, open circle - sample without aquatic biomarkers.

CHRONOLOGY

Prior to this study, only seven dates made on GAC materials throughout the Eastern Baltic were available (Table 3). Here, we redated the GAC cattle burial from Krasnasieĺski (Poz-89315: 4105 ± 35 BP) since the previous measurement (Gd-9249: 4080 ± 140 BP) had a large margin of error. Moreover, we felt it was necessary in light of the recent redating of Stone and Bronze Age human skeletal remains from Lithuania which has demonstrated significant disparities between 'new' and 'legacy' dates (Piličiauskas et al. 2017). We also dated two foodcrusts adhering to GAC potsherds from Tamula (FTMC-17-35: 4618 ± 48 BP) and Daktariškė 5 (FTMC-17-34: 4283 ± 38 BP). Furthermore, we dated the bones of two fish, including a modern white bream (*Blicca bjoerkna*) from the River Virvytė, an outflow from Lake Biržulis (FTMC-17-14: 209 ± 48 BP), and an archaeological common bream (*Abramis brama*) from Daktariškė 5 (Poz-85880: 6330 ± 40 BP), which is also situated on the same lake to explore the impacts of the local freshwater reservoir effect(s).

A total of 10 dates were then used to reconstruct the chronology of GAC type vessels in the Eastern Baltic (Table 3; Fig. 14). When calibrated, there was a very wide date range from ca. 3500-2600 cal BC meaning that the GAC started in the Eastern Baltic before Central Europe (Szmyt 2001; Woidich 2014). However, there is evidence that the oldest dates made on foodcrusts are significantly affected by either a local freshwater and/or marine reservoir effect (hereafter FRE and MRE respectively). For instance, the Šventoji 1 and 2/4 sites are situated in the middle of an ancient lagoonal lake. By dating fish and seal bones from contexts of known age, a FRE in the order of 320-510 years was estimated for the Šventoji palaeolagoon at ca. 3000 cal BC, whilst a MRE of 190 ± 43 years was determined for the south-eastern coast of the Littorina Sea (Piličiauskas & Heron 2015). Offsets of 240 ± 69 and 300 ± 49 years were also determined for dates obtained from Subneolithic ware foodcrusts, which are largely comparable with the estimated FREs and MREs here.

The generally higher bulk $\delta^{15}N$ values (10.0 and 9.8‰) of two of the three dated GAC foodcrusts from the Šventoji sites are similarly likely due to an aquatic source of the residues. Consequently, their radiocarbon ages (Hela-2476: 4625 ± 32 BP; Hela-2477: 4507 ± 32 BP) are very likely affected by a local FRE. The third dated GAC foodcrust from Šventoji, however, had a younger radiocarbon age (FTMC-17-20: 4220 ± 41 BP) as well as a lower $\delta^{15}N$ value (4.3‰). Although organic residue analysis demonstrated that a mixture of aquatic and ruminant adipose fats as well as plant waxes had been processed within the vessel, an aquatic contribution to C was, perhaps, negligible since the date did not significantly diverge from the radiocarbon age of a wooden artefact (Poz-66916: 4135 ± 35 BP) that was located directly underneath another GAC potsherd nor the radiocarbon age of charred lime (*Tilia* sp.) bast (?) rope that was preserved inside a drilled repair hole from an additional GAC potsherd (Poz-64693: 4260 ± 30 BP). Whilst the radiocarbon age of 4220 ± 41 BP (FTMC-17-20), does not significantly differ to those that were securely attributed to the GAC, it is considerably different to those obtained from the GAC foodcrusts (Hela-2476: 4625 ± 32 BP; Hela-2477: 4507 ± 32 BP) that yielded aquatic biomarkers by 405 ± 52 and 287 ± 52 years respectively. These offsets, however, do not exceed the estimated FRE of between 320-510 years for the Šventoji palaeolagoon that was previously established (Piličiauskas & Heron 2015).

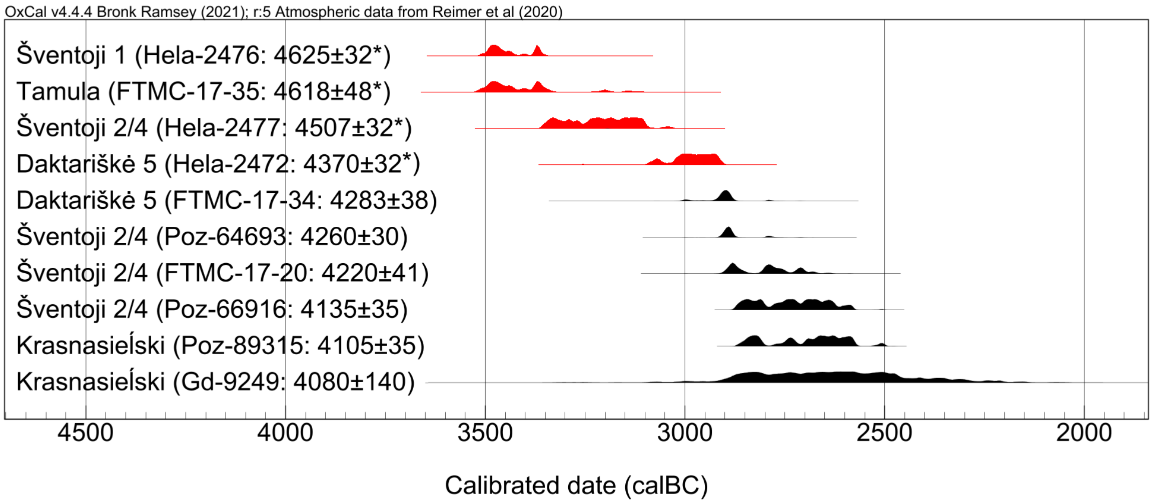

Fig. 14. Calibration plot for GAC materials from five sites in the Eastern Baltic. Dates are from Kadrow & Szmyt (1996), Piličiauskas et al. (2011), Piličiauskas & Heron (2015) and this study. * - dates likely affected by a local FRE are in red.

Indeed, organic residue analysis of modern foodcrusts obtained during experiments has revealed that the full suite of aquatic biomarkers (i.e. APAAs with 16, 18, 20 and/or 22 carbon atoms together with at least one isoprenoid fatty acid (i.e. TMTD, pristanic acid or phytanic acid)) can be formed, even when raw fish represents as little as 10% of the processed resources (Hart et al. 2018). This implies that when aquatic biomarkers are identified within foodcrusts they may have a negligible impact on reservoir offsets in some cases, even when a significant FRE is presumed. Overall, then, only one of the foodcrusts (FTMC-17-20: 4220 ± 41 BP) yielded a somewhat reliable age for the Šventoji sites. Consequently, the others cannot be securely corrected, and have been omitted from further discussion.

Ascertaining the local FRE of Lake Biržulis was an additional aim of the study since two GAC foodcrusts from Daktariškė 5, located on its shore, have been dated. A FRE of ca. 1000 years was determined by the offset between the ^{14}C date of the common bream bone (Poz-85880: 6330 ± 40 BP), and the ^{14}C age of the gyttja horizon it was found in. The age of the gyttja horizon was roughly interpolated from two ^{14}C dates of hazelnut shells (Poz-89302: 4780 ± 35 BP and Poz-85279: 5580 ± 35 BP) uncovered from neighbouring gyttja horizons above and below the dated bream bone (Fig. 15). The established FRE is, however, only applicable for ca. 4100 cal BC as the FRE is variable over time (Keaveney & Reimer 2012). A modern white bream, caught at the outlet of the River Virvytė from Lake Biržulis in 2017, yielded a radiocarbon age of 209 ± 48 BP (FTMC-17-14), which equates to a FRE age of 407 years if we use the atmospheric radiocarbon activity of 102.5 pMC from 2017 (Palstra & Meijer 2021). Thus, it may be assumed that a FRE in the order of between 1000 and 400 years existed for Lake Biržulis during the GAC period.

From Daktariškė 5 two GAC foodcrusts have been dated: Hela-2472: 4370 ± 32 BP and FTMC-17-34: 4283 ± 38 BP, which had corresponding δ^{15}N values of 7.4 and 5.9‰ respectively (Table 3). In a similar vein to Šventoji, the foodcrust with the higher δ^{15}N value had an older radiocarbon age than the other. However, the difference between both measurements is less than the one observed at Šventoji. Organic residue analysis of those very foodcrusts from Daktariškė 5 demonstrated that the vessels had been used to process a combination of aquatic and ruminant adipose fats (Robson et al. 2019). Moreover, the date of the foodcrust with the lower δ^{15}N value (FTMC-17-34: 4283 ± 38 BP; δ^{15}N = 5.9‰) aligned with the reliable GAC dates from the Eastern Baltic as a whole (Fig. 14), and was perhaps not significantly affected by the local FRE of Lake Biržulis either.

To ascertain when Tamula had been occupied during the GAC, we turned our attention to the foodcrusts. Although the bulk δ^{15}N values demonstrated that aquatic products had likely been processed in the vessels, we dated the one (FTMC-17-35) with the lowest δ^{15}N value (9.4‰). Although likely unreliable due to the local FRE of Lake Tamula, the radiocarbon age of 4618 ± 48 BP, corresponding to 3526-3109 cal BC, can be used at best as a *terminus post quem* for the arrival of GAC type vessels at the site.

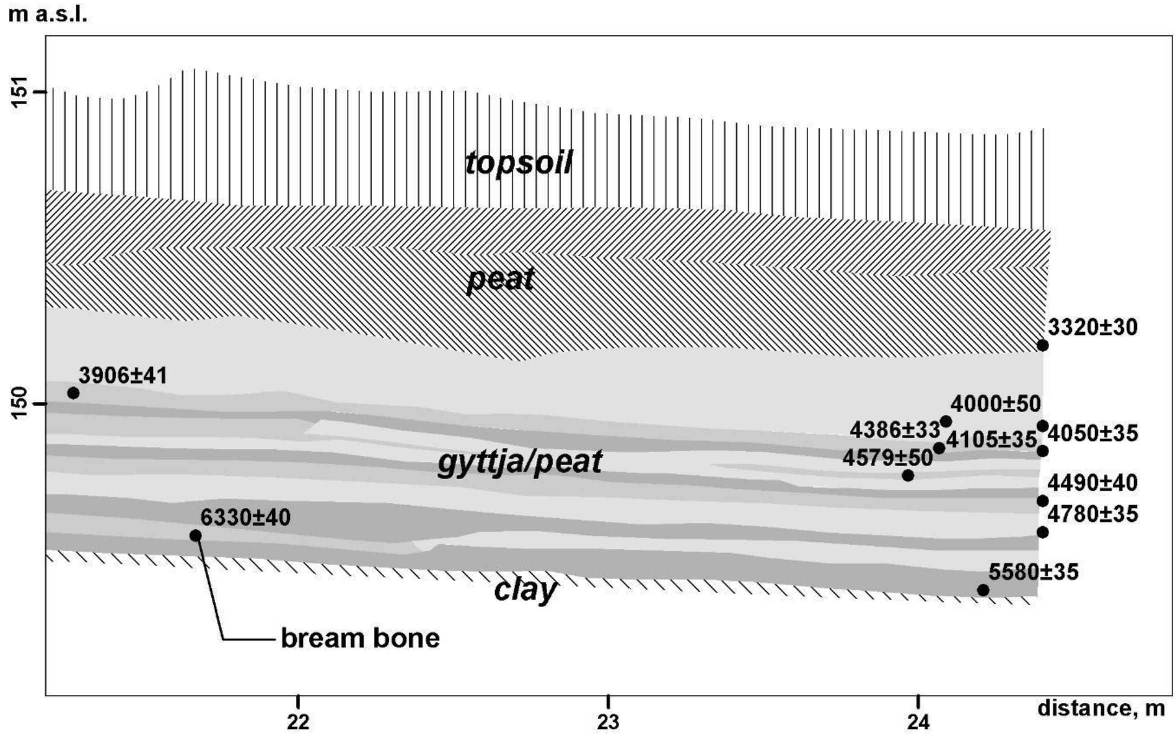

Fig. 15. Digitised section from the Daktariškė 5 site, western Lithuania, with wood samples and their uncalibrated radiocarbon ages. Note the common bream bone date that is affected by a local FRE. Excavations in 2016 by GP.

Indeed, additional data concerning the FRE of Lake Tamula during prehistory exists. An offset of 750 ± 107 years was determined on account of a date obtained from a human mandible (Ua-43123: 4830 ± 39 BP) and a piece of wood (Ta-219: 4080 ± 100 BP), which were both recovered from burial XXII (Tõrv 2019, Table 20). A further offset of 402 ± 42 years was determined between the date obtained on a human bone (KIA-48838: 4995 ± 22 BP) and a piece of pine wood (UBA-28201: 4593 ± 36 BP), which were both recovered from burial IX (Tõrv 2019, Table 20). Overall, this implies that the local FRE of Lake Tamula was at least 750 years at ca. 3000 cal BC. Unfortunately, it is impossible to use these offsets for correction of the dated foodcrust (FTMC-17-35: 4618 ± 48 BP) as the proportion of aquatic and/or terrestrial products could not be estimated. Here, we assumed that the foodcrust date was affected by at least several hundred years, thus, its actual age likely falls within the chronology of securely assigned Lithuanian GAC materials, i.e. ca. 2900-2700 cal BC (Fig. 14).

If we reject the dates affected by local FREs, only six dates from three GAC sites are available; their medians point to a period of activity from ca. 2900-2675 cal BC in the Eastern Baltic (Table 3). Since the CWC of the region dates from ca. 2800-2400/2000 cal BC (Lõugas et al. 2007; Piličiauskas 2018; Kriiska & Nordqvist 2021) it seems that GAC groups moved north from the Nemunas River basin at the same time as the earliest CWC communities or slightly earlier, perhaps by ca. 100 years. Both cultures, however, likely coexisted side-by-side for at least one hundred years. Overall, it may be hypothesised that GAC migrants firstly arrived at the south-eastern Baltic coastline where they contributed to the formation of the RC at ca. 3200 cal BC (Fig. 1; Saltsman 2013; Piličiauskas & Heron, 2015) before leapfrogging further to the north at ca. 2900-2700 cal BC.

SUMMARY AND CONCLUSIONS

GAC AND CWC IN THE EASTERN BALTIC: DIFFERENT SCALES AND IMPACTS

GAC and CWC communities primarily herded domestic livestock in other regions throughout Central Europe (Szmyt 1996b; Kadrow 2008; Woidich 2014), however, they had to adapt their economies in the Eastern Baltic, an area that differed both climatically and environmentally. Indeed, their lifeways throughout the areas of occupation were far from homogenous. In the Eastern Baltic, GAC communities appear to have reorientated their economy towards fishing on a much greater scale than their CWC counterparts, markedly contrasting with other regions.

At ca. 2800-2700 cal BC, GAC and CWC peoples presumably met one another in the Eastern Baltic. Nevertheless, they maintained specific pottery and lithic traditions. To date, there is no evidence to support any form of hybridisation in terms of material culture. Although a fragment of a banded flint axe, recovered from the CWC site of Karaviškės 6 (Piličiauskas 2018, 49:11f.), may indicate some form of contact or exchange between GAC and CWC groups, this interaction likely took place in Central Europe rather than the Eastern Baltic. Polished square axes made of Jurassic banded flint were produced in large numbers by GAC peoples at the Krzemionki mines in southern Poland (Borkowski & Budishewski 1995), almost 600 km to the south-west of Karaviškės 6.

Overall, it is becoming increasingly apparent that the expansion of the GAC and CWC into the Eastern Baltic represents two Neolithisation events with distinct cultural and economical traits. Initially, GAC migrants appear to have settled along the coastlines of modern day

Poland, Kaliningrad and Lithuania where they contributed to the formation of the RC *ca*. 3200 (see below). Based on the scarce material in the northern regions of the Eastern Baltic we can hypothesise that sporadic GAC groups may have moved further north. However, further evidence to support this notion from material culture and biomolecular data (especially aDNA) is required in the future. At the same time or a century later, CWC peoples moved into the region, and then diffused into southern and western Finland reaching as far as the northern coastline of the Gulf of Bothnia (Nordqvist & Häkälä 2014).

Not only the occupied territories of both groups differ but also their impacts on the indigenous peoples throughout the region. Indeed, their cultural and economic development also took different trajectories. Throughout the majority of the Eastern Baltic, GAC material culture on the whole is scarce. This implies that soon after the GAC might have dispersed into the region, isolated groups either assimilated material culture from indigenous peoples or returned to their homelands to the south. However, the south-eastern Baltic coastline witnessed a different phase of development. It is, perhaps not inconceivable, that the presence of amber initially attracted an increasing number of Neolithic peoples to the area compared with inland regions. In support of this, the largest GAC pottery assemblages throughout the Eastern Baltic were obtained from the sites of Šventoji 1 and 2/4, which are located near rich sources of amber (Fig. 16). From here, amber is likely to have been transported to the interior as evidenced by its presence at the GAC sites of Daktariškė 5 and Tamula, located far from the coast.

At ca. 3200 cal BC these pioneers evolved to form a novel cultural group represented by the RC (Piličiauskas & Heron 2015). The earliest known RC pottery throughout the region, recovered from the site of Pribrezhnoye in Kaliningrad, is indeed, very similar to that of the GAC (Saltsman 2004; 2013), whilst a CWC influence on the pottery tradition is only evident during the latest stage of RC pottery, and dated to ca. 2500 cal BC (e.g. the site of Nida (Rimantienė 1989; Piličiauskas & Heron 2015)). Instead of the introduction of a mobile way of life and economy based on animal husbandry, GAC migrants at RC settlements practised a sedentary way of life and engaged heavily in fishing and marine mammal hunting.

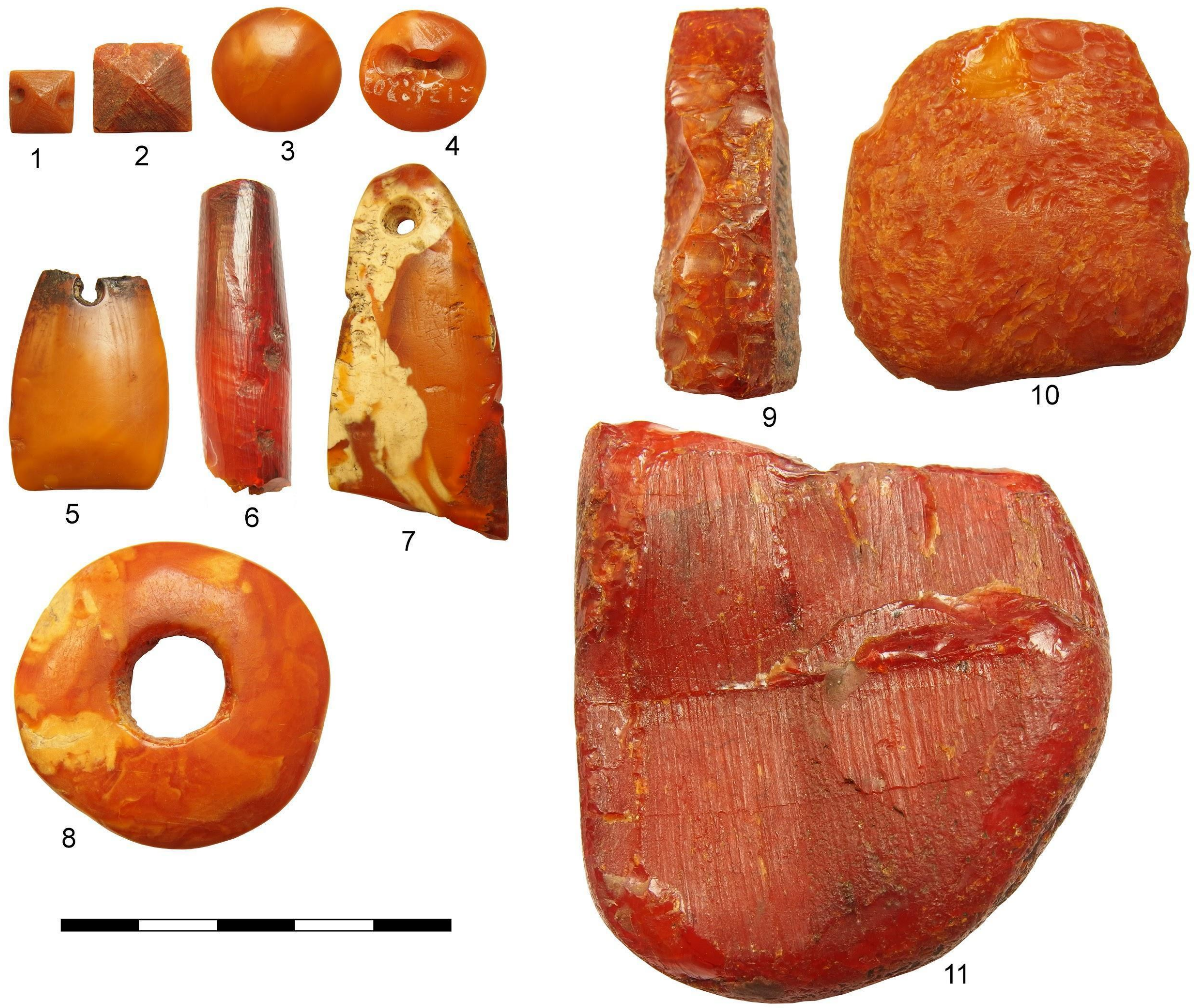

Fig. 16. Amber ornaments (1-8) and preforms (9-11) from the Šventoji 1, 4, and 6 sites, which included both Subneolithic and GAC ceramics.

Between ca. 2900 and 2700 cal BC GAC groups moved further north, probably along the coastline until they reached the Šventoji palaeolagoon. Coastal GAC sites are unknown north of Šventoji, and rich sources of amber are absent, which is perhaps not coincidental. In the Šventoji area there is no evidence for interaction between GAC groups and local foragers in terms of material culture compared with the RC. For instance, the presence of oval bowls, assumed to be lamps, were adopted by RC peoples from the preceding Subneolithic foragers. It is possible that a localised population replacement took place here, and elsewhere, for instance the environs of Lake Biržulis (e.g. the sites of Daktariškė 1 and 5), which is situated 80 km to the east from the Lithuanian coastline. In other areas of the Eastern Baltic, GAC sites are much rarer and usually yield little in the way of material culture. Overall, their impact is largely invisible.

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