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AN INTEGRATED RESULT OF GIS-BASED APPROACH TO PALAEOGEOGRAPHICAL RECONSTRUCTIONS AND ARCHAEOLOGICAL SURVEYS OF COASTAL PALAEOLAGOONS AT THE MOUTHS OF THE RIVERS VIHTERPALU, TEENUSE AND VELISE (WESTERN ESTONIA)

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Methods of palaeogeographical modelling of possible freshwater bodies based on open access datasets provided by the Estonian Land Board are discussed, along with the landscape use of the recently surveyed palaeolagoons at the mouths of the rivers Vihterpalu, Teenuse and Velise (western Estonia) after Litorina Sea transgression maximum (ca 5300 BC). The site clusters by the Vihterpalu palaeolagoon can be dated to the Pre-Pottery Mesolithic or Narva stage (until 5200 BC and 5200–3900 BC, respectively). Human activity by the Velise lagoon probably started at the same time and intensified during the Comb Ware stage (3900–1750 BC). Two mineral surface depressions, sufficient to accommodate remnant lakes and presently covered by peat layers of mires deserve further attention. They are located in the Seljaküla, Variku and Keedika villages behind the coastal formations observable by the road connecting the Keila–Haapsalu main road with Nõva village. Similar depressions behind the coastal formations in the Teenuse–Velise area are not sufficient for freshwater bodies. The spatial pattern of small-scale aceramic settlement sites by the tributaries of the present-day River Kasari up to 10 km from the palaeocoastline suggests a highly persistent seasonal land use during the Comb Ware stage, comparable to the Neolithic settlement phase of Kunda Lammasmägi.

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Introduction

In this paper we discuss geoinformatic methods of palaeolandscape modelling based on publicly available datasets provided by the Estonian Land Board. For a comprehensive study of land use patterns, palaeolandscape reconstructions of both coastlines and freshwater bodies in the coastal vicinity need to be integrated with the results of archaeological surveys. It is argued below that publicly available open access datasets provide a good starting point for mapping possible palaeolakes beneath later organic sediment layers of peat mires.

Not surprisingly, historical shoreline changes first attracted attention in northern Europe where the phenomenon of relative sea-level drop was too pronounced to be ignored, with the research history having its beginning in the 18th century (for a brief overview, see Pirazzoli 1991, 1–6). During the first half of the 20th century, shoreline displacement became widely discussed by archaeologists (e.g. Europaeus 1926; for a contemporary review, see Clark 1936, 7–22). The first well-documented Holocene sea-level curves in the world were assembled by the Swedes (Granlund 1932; Lidén 1938), soon to be followed by the British (Godwin 1940). The method gained more popularity worldwide with the advent of radiocarbon dating, and even more so during the rise of processual archaeology following its interest in environmental adaptions (e.g. Siiriäinen 1974; Kraft et al. 1985).

Much inspired by contemporary Finnish archaeology, the methodology of palaeolandscape reconstruction for coastal areas and coastline displacement chronology became routinely used and discussed in Estonian archaeology already before World War II (e.g. Tallgren 1922, fig. 4; Laid 1931, 355–358; Indreko 1932; Moora 1934, 256–257; Moora et al. 1935, 16–17, 30–32, fig. 33; Moora 1938, 248–252; Indreko 1948; for historiography, see Jaanits 1961; Lõugas 1988, 16; Kriiska & Lõugas 2006, 271–272) but experienced a decline during the Soviet occupation (Jaanits 1961; Rõuk 1992, 57; for the administrative restrictions on the work of Helgi Kessel (e.g. 1961), see Moora et al. 2016, 11–13). The interest was revived shortly after the restoration of independence (Rõuk & Vuorela 1992; Mandel 1993, 19; Raukas et al. 1999), and palaeocoastline reconstruction together with applications of refined coastline displacement chronology has been standard practice since the 2000s (Saarse et al. 2003; Jussila & Kriiska 2004; Saarse et al. 2006 and references therein; 2009a; 2009b; Rosentau et al. 2011; Grudzinska et al. 2013; Rosentau et al. 2013; Moora et al. 2016; Habicht et al. 2017; Muru et al. 2017; Rosentau et al. 2020; Nirgi et al. 2017; Muru et al. 2018; Nirgi et al. 2020). The present paper relies on the modelled former sea levels and locations of the coastline (Fig. 1: left) reconstructed by coast displacement curves for south-western Estonia (Rosentau et al. 2011), Tallinn (northern Estonia; Muru et al. 2017) and Lake Veskijärv (near the northern study area; Grudzinska et al. 2013), considering the post-glacial rebound (Saarse et al. 2003; 2006), published by Sander & Kriiska (2021).

Palaeogeographical reconstruction of Estonian inland freshwater bodies has been attempted less often (but for Kroodi palaeolake, see Orviku 1936; for valley terraces,

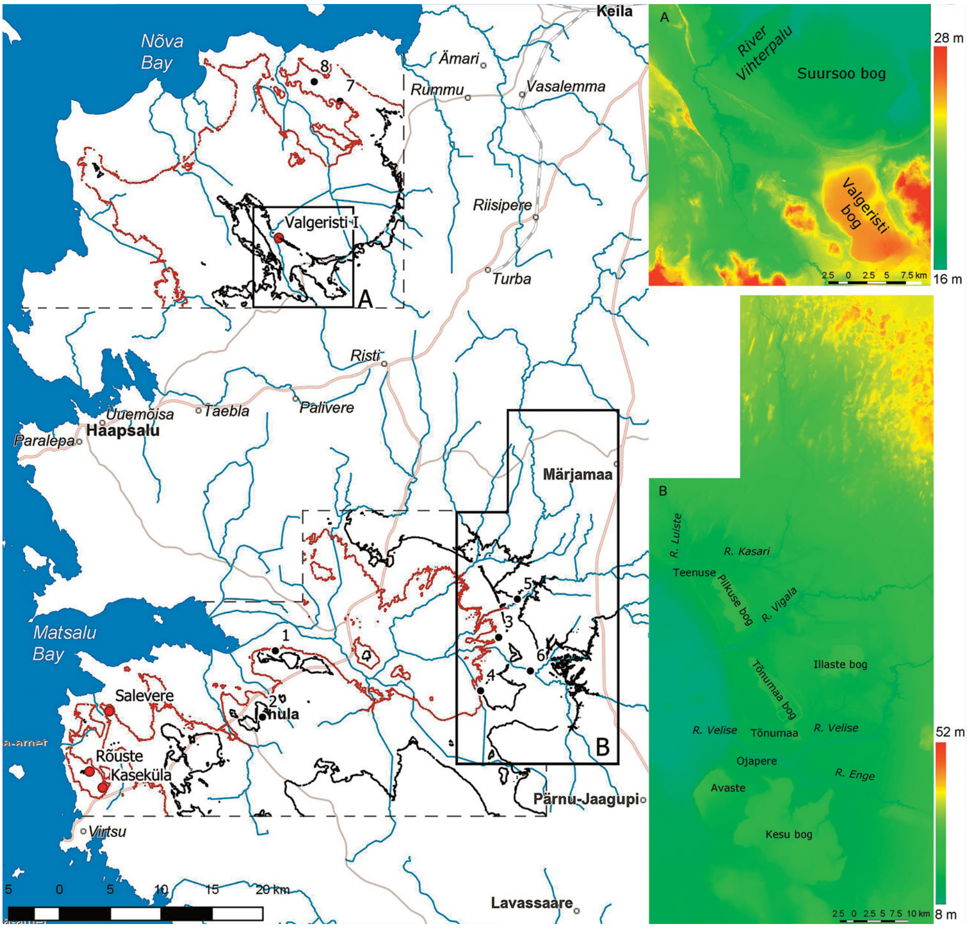

Fig. 1. Left – location of the study areas of the present paper by the rivers Vihterpalu (A) and Velise (B) in western Estonia, palaeocoastlines 5300 cal BC (black) and 4000 cal BC (dark red), previously known settlement sites (red dots) and stray finds (black dots: 1 – Kloostri, 2 – Lihula, 3 – Oese, 4 – Avaste, 5 – Tiduvere, 6 – Kesu I, 7 – Harju-Risti, 8 – Vilivalla), as well as the study areas of the entire Stone Age West Estonian Lowland Project (dashed line; Sander & Kriiska 2021, fig. 1) displayed on the present-day map. Right – modern relief of the modelled areas and their immediate surroundings, provided by the Estonian Land Board.

see Hang et al. 1964 and references therein; for Lake Võrtsjärv, see Tallgren 1922, fig. 6; Orviku 1973 and references therein; Moora et al. 2002; for the Akali settlement site near the mouth of the River Emajõgi, see Moora et al. 1988; for Lake Peipsi, see Hang & Miidel 2008; for water bodies of Late Iron Age and medieval Tallinn, see Mägi & Karro 2015). Regarding palaeolakes in the places of later mires, the most prominent example of research co-operation between archaeologists and geologists is the research history of the palaeolake and the later mire around the Stone Age settlement site of Kunda Lammasmägi (Orviku 1948; Karukäpp et al. 1996; Moora

& Moora 1996; Moora et al. 1996; Moora 1998; Sander & Kriiska 2018). However, for the overwhelming majority of Estonian mires, geological data is not available in comparable detail either in spatial (extent and thickness of peat layers) or temporal (pace of peat accumulation) terms. The need for developing a cost-effective method to assess the possibility of palaeolakes in large areas necessitated the present attempt to use the Estonian Soil Map together with the Digital Terrain Model (Estonian Land Board 2017; 2021) and the database of stratigraphically described peat layer sampling sites (Orru 2020) for the initial verification of the possibility of sufficient depressions in coastal areas. This GIS-based approach used in the present work is novel for Estonia, although much more detailed surface coverage interpolations (e.g. SGU 2021) or palaeogeographical models combining multiple data sources (e.g. Pierik et al. 2016) have been published elsewhere.

Palaeolandscape models of three river-mouth palaeolagoons at the western coast of Estonia (River Vihterpalu (Fig. 1: A) and the rivers Teenuse and Velise (Fig. 1: B)) during the period between ca 5300 BC (final part of the Pre-Pottery Mesolithic, concurrent with the Litorina Sea transgression maximum, hereinafter LTM) and ca 2000 BC (final part of the Neolithic; Fig. 2) are presented as case studies, together with the results of archaeological surveys conducted in the same area in 2015–2017 and in 2020. The archaeological surveys were part of a wider project to map the Stone Age settlement process in the West Estonian Lowland, discussed by the authors elsewhere in a more general manner (Sander & Kriiska 2021).

During the LTM, shallow lagoons were formed at the mouths of the rivers Vihterpalu and Velise, separated from the sea (by the Nõva and Matsalu palaeobays, respectively) by barrier islands. A third, smaller lagoon was formed in the Teenuse area. By the Vihterpalu lagoon one settlement site (Valgeristi I) was previously known, but from the Teenuse–Velise area only stray finds are known so far (Kriiska 2001). In total, 45 settlement sites and 18 stray find locations were discovered during the recent fieldwork in the study areas of the present paper. Presently, both modelled areas feature large raised bogs (Fig. 1: right; Fig. 3) and a number of smaller peatlands. The Suursoo and Leidissoo bogs and the Avaste bog west of the Avaste hill are situated at the LTM sea bottom, while the Valgeristi, Pilkuse, Tõnumaa and Kesu bogs have formed in depressions behind the coastal formations or former barrier islands of the lagoons.

Materials and methods

Palaeolandscape modelling

Three types of source data were used, all provided by the Estonian Land Board:

1. Digital Terrain Model (DTM) *points* (Estonian Land Board 2021).
2. Digital Soil Map (DSM) shapefiles (Estonian Land Board 2017). This open specification file format developed by the Environmental Systems Research Institute (ESRI) spatially describes vector features such as polygons, lines or

points (ESRI 1998). In the present case, the data is organized into *polygons* associated with relevant metadata such as soil type, thickness, granulometric composition, etc. (Fig. 3).

3. Database of stratigraphically described peat layer sampling (Orru 2020; Fig. 3: white dots).

DTM points, DSM polygons and the stratigraphy of sampling sites all suffer from different constraints. The DTM accurately describes the current situation, including later developments such as secondary lakes or streams in the upper part of the peat layer or manmade excavations, ditches or roads. The latter are easily

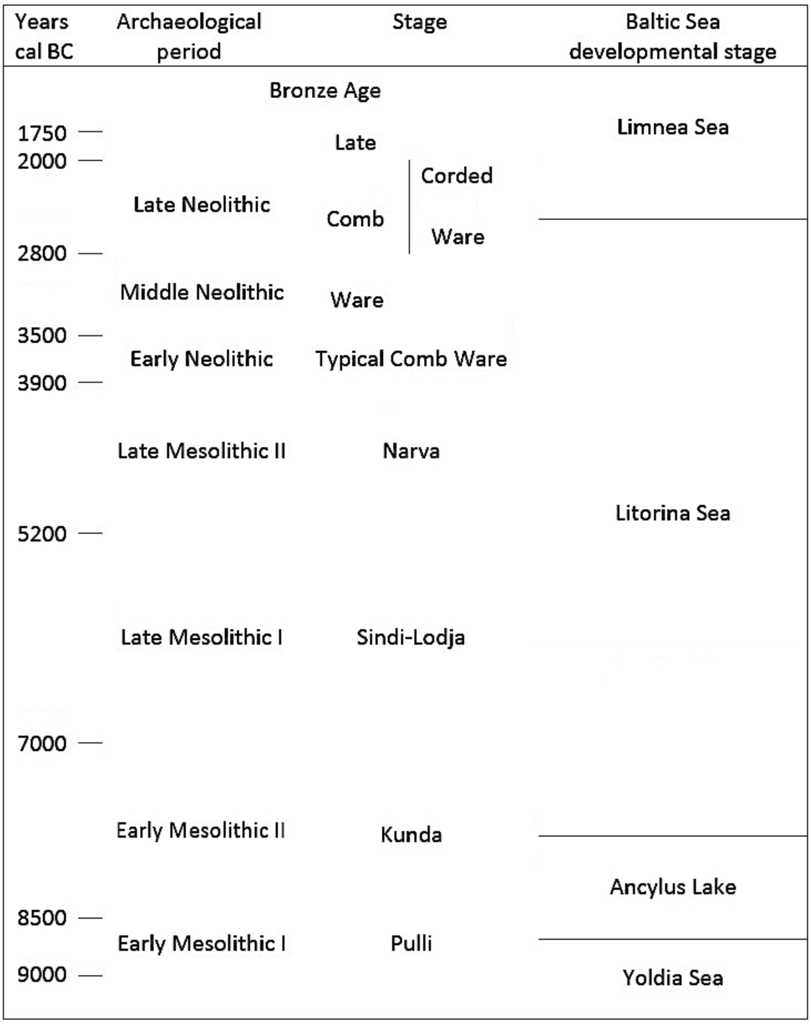

Fig. 2. Estonian Stone Age periodization together with Baltic Sea developmental stages (Hang et al. 2020; Kriiska et al. 2020, 17).

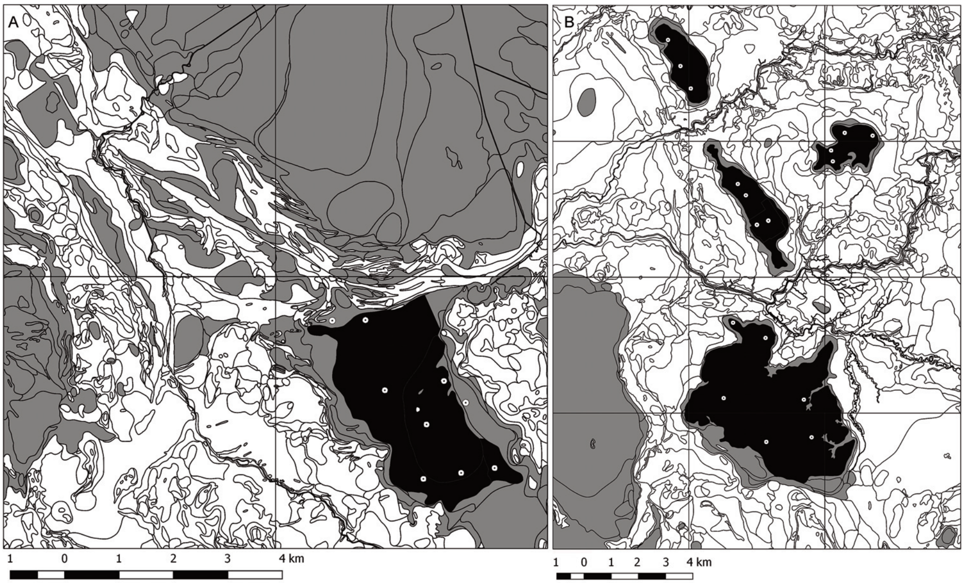

Fig. 3. Digital Soil Map polygon borders provided by the Estonian Land Board of the Vihterpalu (A) and Velise (B) palaeolagoons and the surroundings. Central polygons of raised bogs are in black, marginal polygons in grey. White dots denote previously described sampling sites (Orru 2020).

recognizable by their regular shape and can be removed manually or with the help of numerous available algorithms beyond the scope of the present work.

The maximum extent of peat layers mapped in the DSM is often limited to 150 cm below the present surface, necessitating interpolation of deeper surfaces by sampling site data. Typically, the DSM provides usable peat layer thickness values for the polygons surrounding the highest part of the peat dome (*marginal polygons*; Fig. 3: grey) and the previously described sampling sites (if present) for the *central polygon* (Fig. 3: black). Penu et al. (2014) list a number of issues concerning the data quality of the DSM. In order to process a large amount of data and to get a reasonable outcome, these issues need to be addressed in an algorithmic way. Most of the data manipulation described below is needed to correct discrepancies between the DSM and the DTM such as polygon borders not following the actual slope of the corresponding peat dome.

The stratigraphic descriptions of sampling sites are the most precise data source. However, the sampling sites may not cover the central polygon sufficiently and their locations do not reflect the exact shape of the depression bottom. As for lacustrine sediments, the gyttja layer of remnant lakes is often thin (5–20 cm; Saarse 1994) and besides that, the stratigraphic descriptions sometimes lack lacustrine sediments known from other sources (e.g. Orru 2020, Kaisma_6) and cannot therefore be treated as decisive for modelling possible palaeolakes. Occasionally, the sampling sites do not penetrate the organics layer and do not reach the underlying mineral surface at all.

A Python script was developed to combine and process the data, creating point clouds as output, the source code of which is available upon request. All steps of the data processing sequence use either DSM polygons or DTM points or both as input. DSM polygons with soil types M, S and R were treated as having an extensive peat layer and others as lacking it (hereinafter *peat polygons* and *non-peat polygons*). For each polygon, thicknesses of peat layers are extracted algorithmically from the relevant DSM metadata field and DTM points are indexed by DSM polygons where possible.

The subsequent workflow is as follows (leaving aside technicalities such as excluding polygons with very small areas, joining adjacent polygons with identical designations, etc.):

1. associating polygons with points by creating one-to-many relationships;
2. correcting discrepancies between the borders of peat polygons and DTM features (slopes of the real-world peat domes);
3. creating a sample of the surrounding ground surface elevation for each bog;
4. modelling the peat layer and subtracting its thickness from the present-day DTM.

The second and fourth points deserve closer attention. The borders of DSM peat polygons are often drawn in a generalized manner and do not precisely match the real-world entities (Fig. 3: A). To correct this, the mean elevations (Z-coordinates) of points are calculated for each polygon and the points with Z-coordinates closer to the adjacent polygons are transferred or deleted and interpolated later. This simple method proves sufficiently effective, especially for the surrounding ground (Fig. 4).

The palaeosurface elevation *z'* of marginal polygons is modelled point by point linearly by the minimum and maximum values (*tmin, tmax*) of the peat layer thickness for the polygon obtained from the DSM, and the difference of the minimum and maximum present-day surface elevation (*zmax, zmin*) of the same

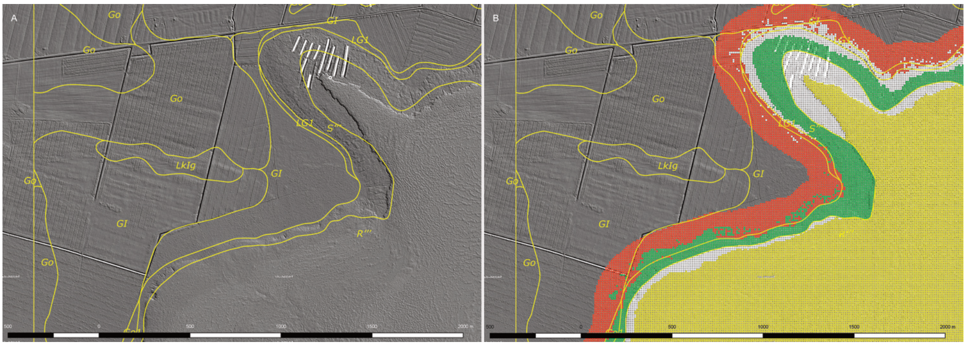

Fig. 4. A – DSM polygon borders (yellow) projected upon DTM (greyscale) of the NW corner of the Kesu bog provided by the Estonian Land Board. B – point clouds used for palaeolandscape modelling (yellow: central polygon, green: marginal polygon, red: surrounding ground sample without extensive peat layers, white: points that will be excluded and interpolated later). The coloured point clouds follow the real-world slopes more closely.

polygon and the present-day elevation of the point (z) obtained from the DTM as follows (Fig. 5):

$$z' = \frac{zmax - z}{zmax - zmin} * (zmin - pmin - zmax + pmax) + zmax - pmax.$$

For each point in a peat polygon, the mean of a sample of the closest points of the surrounding ground is calculated in step 2 (*zref*). If the present-day peat surface elevations of the polygon are correlated with *zref* (Pearson's correlation coefficient >0.6, p <0.05), the modelled elevation is corrected by *zref* to avoid excessive subtraction. The final result is checked against *tmin* and *tmax* (to fit between them) and *zref* (not to exceed it).

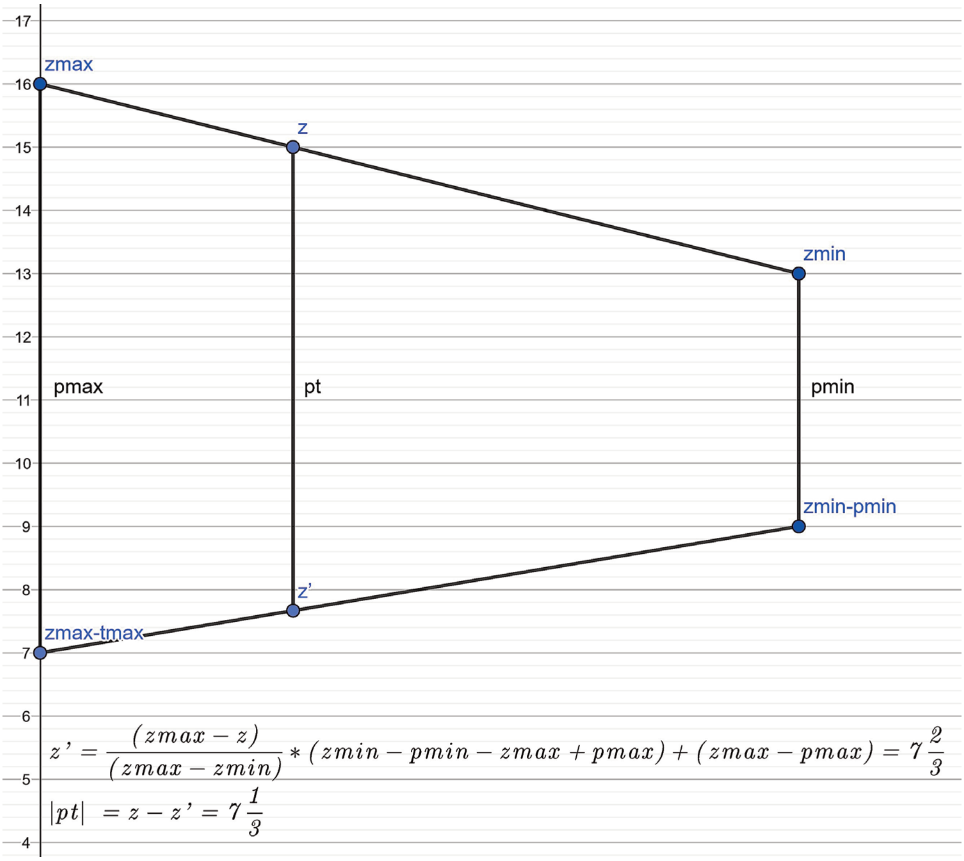

Fig. 5. Modelling of the palaeosurface elevation *z'* under the peat layer with the maximum and minimum present-day elevations *zmax* and *zmin* and the maximum and minimum thicknesses *tmax* and *tmin* for a point with the present-day elevation *z*. The trapezium represents the cross-section of the hypothetical peat polygon in the raised bog.

This approach does not work well for large central polygons of raised bogs, usually featuring peat layer thicknesses beyond the DSM vertical resolution (usually up to 150 cm). The elevation differences of the central plateau are not indicative of the palaeosurface elevations below the peat dome because most of the variability is caused by secondary landforms such as streams, bog ponds, man-made ditches, drainage and peat mining. If the sampling sites sufficiently cover the central part of the raised bog, the *central palaeosurface* between them can be interpolated by their stratigraphy, representing the minimal area of the depression bottom. If not, an educated guess for the central palaeosurface could be *zmax – tmax* within reasonable spatial limits (inner third of the central polygon or such). Depending on the trustworthiness of the DSM data on marginal polygons around the central polygon, the elevations between the edge of the central polygon and central surface can be interpolated by the sample of the modelled palaeosurface of the closest marginal polygon or the surrounding ground.

Either of the above methods results in a bowl-like profile characteristic of raised bogs succeeding a Boreal lake or a valley bog (e.g. Masing 1988, 11, fig. 2A and 2E) with gaps interpolatable by a variety of available algorithms. In the present study, the Triangle library implementation of the Delaunay interpolation included with the CloudCompare computer software was used (Shewchuk 1996; 2002 and references therein). As the research areas are situated near the former coastlines dating to the LTM or later, having gradually become habitable because of lowering sea levels, and both the typological dating of the archaeological finds and the dating of the sites by coastal chronology agree on the coastal or near-coastal location of the sites (Sander & Kriiska 2021), the question of the rate of organic sediment formation (peat accumulation) is irrelevant for the present work because the peat layers pre-dating the LTM would be buried by non-organic marine sediments and by the time of the formation of the later peat layers, the coastline would have retreated further away. In other words, the present study is concerned with lately exposed "empty" surface cover depressions with minimal organic layers. With the help of the GIS data used in the current study, only the possibility of the existence of depressions sufficiently deep to accommodate remnant lakes could be assessed; the actual existence and development of such lakes can be established by further studies, considering the local water regime, the rate of peat accumulation, the geomorphology of incoming water streams, the exact geomorphology of the buried de- pressions determinable by geophysical methods (e.g. Corradini et al. 2022) and other factors. For the current paper, the former water streams were mapped by the DTM and aerial photographs based on human perception, to verify the spatial association between the sites and fluvial freshwater bodies, not modelling the water levels of palaeolakes.

Archaeological surveys

The primary method of fieldwork was fieldwalking and gathering finds from the surface. Occasionally 30 × 30 × 60 cm test pits were made. At least three spatially close finds were grouped as a settlement site. Groups of finds were recorded as different sites if separated by a visual barrier (most often by afforestation), located at different elevations or spatially associated with coastal formations at different elevations. Therefore, the division of closely located GPS findspots into sites often reflects the present land use and surface conditions. The locations of all findspots were recorded by handheld GPS with a minimum precision of ±8 m.

Finds could only be collected from areas with open ground: agricultural land, gardens, forest clearings and transport routes. Therefore, the quantity of finds for each site does not indicate the intensity or nature of human activity during the time of deposition but the present-day finding conditions. The spatial orientation of the sites does not necessarily reflect the landscape use during the time of deposition either, as two adjacent sites might be separated by a strip of land with more difficult finding conditions. Similarly, the lack of finds from any particular area might be attributed to the lack of open ground.

The routes for fieldwalking traced the coastal formations of Litorina Sea, identifiable from LiDAR elevation models and often visible on the ground. Where possible, adjacent areas at different elevations were also checked for comparison. However, the goal of the fieldwork was to find as many sites as possible, not to survey a statistically representable sample of the surface. The overwhelming majority of finds are spatially associated with coastal formations, water streams or both. This might reflect a research bias towards areas with visible landforms. However, the trend is in line with the current research on the location choice of Stone Age settlement sites in Estonia (Sikk et al. 2020). No effort was taken to survey the areas covered by peat layers.

From the study areas of the present work (Fig. 1), 583 finds were collected. In addition to 668 finds from 45 settlement sites, 23 stray finds were gathered from 18 locations. The locations of most of the sites and stray finds have been published previously (Sikk et al. 2020; Sander and Kriiska 2021), except for the Sipa I–II and Manni I sites, which are published for the first time. Twenty-six sites were in the coastal zone up to 10 km from the coast and only two sites were found further inland (Sipa I–II). Of these, about one third (nine sites) were probably coastal. All sites can be associated with palaeocoast or water streams. No organic material enabling radiocarbon dating was gathered from any of the sites. The approximate dating of the sites is currently possible only by using the coastline displacement model (Jussila and Kriiska 2004; for *terminus post quem* (*tpq*) values of the sites, see Sander & Kriiska 2021, Supp. table 1) and comparatively by archaeological finds.

No sherds of the Narva type were found in the ancient river mouths considered in the current paper. Only 15 sherds of Comb Ware and ten sherds of Corded Ware are present among the finds collected from five sites, all situated in the southern study area (Fig. 1: B): Ojapere II, III, IV, V by the River Velise and Teenuse IX. Although sherds of vessels belonging to only one Stone Age ceramic style were found in some of the Ojapere sites, both styles were present in the Ojapere riverside site cluster stretching more than 13 hectares and at Teenuse IX.

The vast majority of the finds are lithic artefacts. Five lithic finds exhibit signs of secondary processing. These include three flint scrapers, two retouched flint flakes and one flint arrowhead. Two flint flakes and one flint blade bear clear signs of use wear. The evidence of stone grinding is scarce, limited to two adzes from the Ojaküla I and Teenuse II sites. The most common lithic material is quartz, followed by Carboniferous, Silurian and Cretaceous flint and other lithic materials. Flint is identified visually, based on the authors' personal experience with comparative material, including the reference collections of Silurian and Carboniferous flint at the Department of Archeology of the University of Tartu (partially published in Kriiska et al. 2018; Johanson et al. 2021).

Results and discussion

All three of the former river-mouth lagoons (Vihterpalu, Teenuse, Velise) must have formed before the LTM and ceased to exist between 5000 and 4500 BC. The differences in the marine coastline locations between the two study areas at the end of the Neolithic are much more pronounced: while in the Vihterpalu area the coastline had moved at least 5 km away from the LTM coastline by 2000 BC, in the Teenuse–Ojapere–Avaste area it was still less than 1 km west of the former lagoon barriers (Sander & Kriiska 2021). In addition to the marine coastline reconstructions, the combination of the data sources and studies listed above enabled to model a continuous mineral palaeosurface beneath extensive organic layers as well as subsequent palaeogeographical reconstructions for different dates for both areas (Figs 6–8).

The values obtained from the DSM proved to be of limited value for modelling the palaeosurface around well-defined peat domes of the Valgeristi, Pilkuse, Tõnumaa and Kesu bogs, where marginal polygons are often too thin to be of use. However, as the thickness of the organic layers of several peatlands at the bottom of the former Vihterpalu river-mouth lagoon varies only between 30 and 150 cm, the DSM helped to refine the palaeogeography of the Vihterpalu river mouth west of the Valgeristi bog.

The stratigraphic descriptions of the sampling sites (Orru 2020) provide better opportunities for assessing the possibility of remnant water bodies, being available for all raised bogs in the modelled areas. The modelled depressions under the Kesu, Tõnumaa (Fig. 6) and Valgeristi bogs behind the coastal formations allow a maximum depth of only 1 m for a remnant water body. The data does not indicate any considerable depression under the Illaste bog and the central and southern parts of the Pilkuse bog, while the northern sampling site of the Pilkuse bog did not penetrate the peat layer. However, the depression at the site of the former Vihterpalu lagoon south of the road connecting the Keila–Haapsalu main road with Nõva (No. 16150) in Seljaküla, Variku and Keedika villages is sufficiently pronounced to contain a remnant freshwater body about 2.5 m deep (Fig. 7: C). The possibility depends on the local water regime and the geomorphology of the River Vihterpalu,

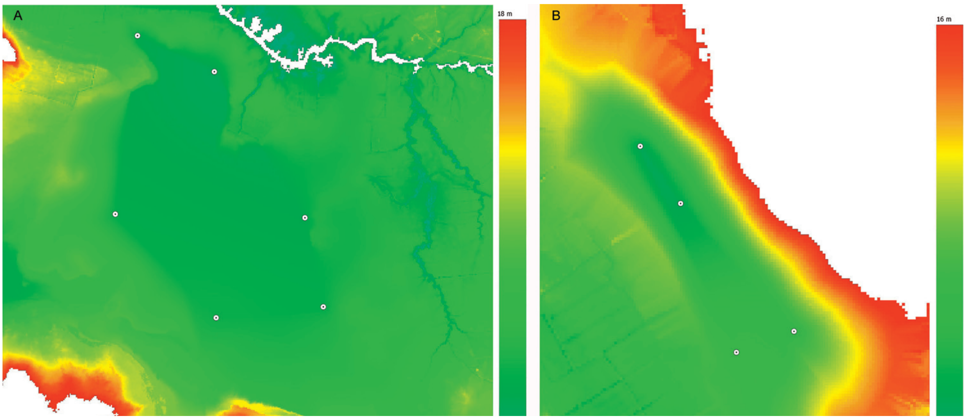

Fig. 6. Modelled palaeosurface of the Kesu (A) and Tõnumaa (B) bogs and their surroundings with relevant elevation colours. White dots denote the previously described sampling sites (Orru 2020).

deserving further study. Presently, no archeological sites have been identified on the shores of the possible remnant lake.

The majority of the settlement sites by the Vihterpalu river-mouth lagoon are spatially associated with LTM coastal formations (Fig. 7: A). The Küünimäe VI and VIII sites (Fig. 7: B) might be slightly later. The sites form two distinct clusters at the western coast (Küünimäe sites, Fig. 7: A, 1–6) and on the barrier island of the lagoon (Valgeristi sites, Fig. 7: A, 7–13). The majority of the finds are of quartz, Silurian flint and other lithics are rare and Carboniferous flint is completely absent. The lack of flint blades does not allow for any of the sites considerably earlier dating than the LTM. Presently, the ancient Vihterpalu river-mouth lagoon is the only one known in Estonia where clusters of probably pre-pottery sites have been discovered and the only one in Estonia where the sites cluster not only at barriers but also at the inner coast.

The Inkatoa I site in the same area can be associated with the River Vihterpalu instead of the lagoon, providing an analogue to the presumably early riverside sites in the southern study area. Leaving aside the Kesu II site, several sites (Tõnumaa I–II, Oese I, Urevere I, Manni I; Fig. 8: A) have each provided a small number of finds of Silurian flint and quartz, while Carboniferous flint is completely absent. Until further studies, it is possible to interpret these finds as signs of Mesolithic human activity, similarly to the small aceramic sites along the shores of the palaeolake surrounding Kunda Lammasmägi (Sander & Kriiska 2018).

Even in the absence of pottery sherds, the sites can be roughly comparatively dated by the share of blades among the flint finds. The share of flint blades (including fragments and tools made from blades) is generally higher in the Estonian pre-pottery Mesolithic (e.g. Pulli, Umbusi, Lepakose, Siimusaare, Ihaste, Sindi-Lodja II, Kavastu, Kivisaare and Jälevere sites, where it ranges from 10% to 40%; Jaanits & Ilomets 1988, 54; Kriiska et al. 2003, 36; Tvauri & Johanson 2006, 42–43;

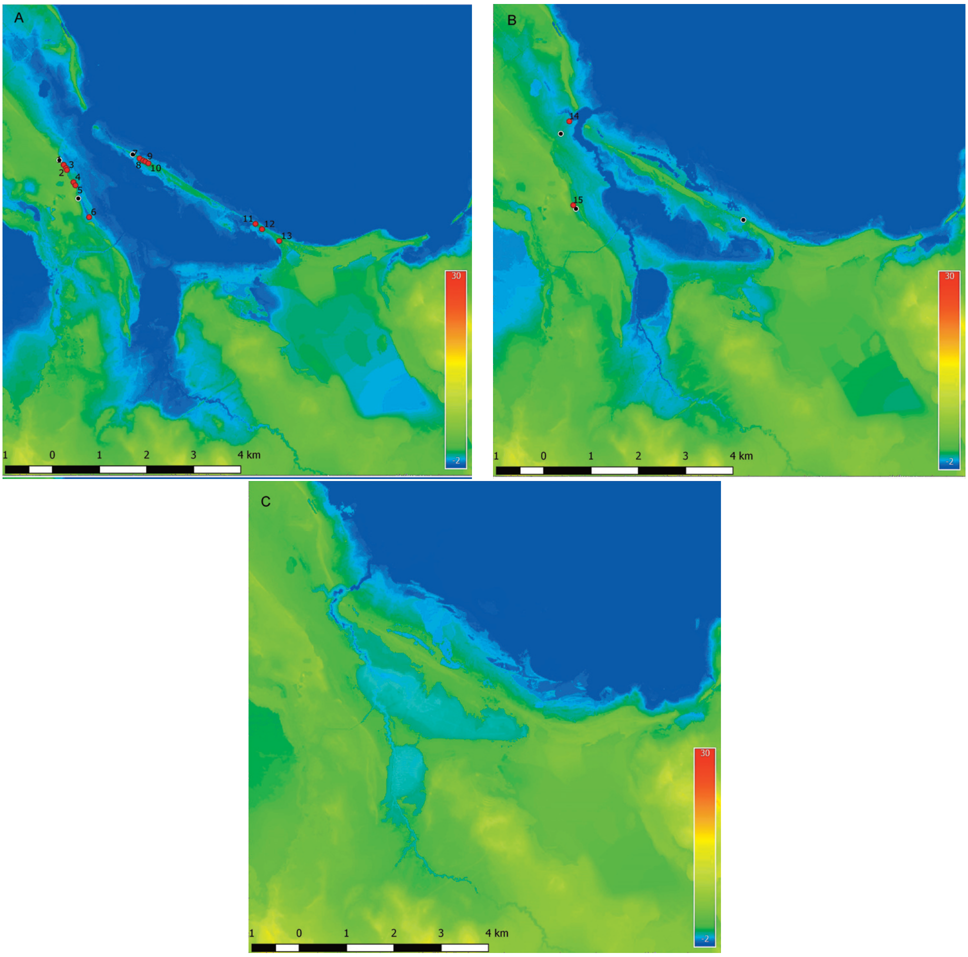

Fig. 7. Palaeogeographical reconstructions of the Vihterpalu river-mouth lagoon, dating to 5300 BC (LTM, A), 5000 BC (LTM, B) and 4500 BC (LTM, C), with settlement sites indicated by red and stray finds by black dots. The settlement sites: 1 – Küünimäe I, 2 – Küünimäe II, 3 – Küünimäe III, 4 – Küünimäe IV, 5 – Küünimäe V, 6 – Küünimäe VIII, 7 – Valgeristi II, 8 – Valgeristi III, 9 – Valgeristi IV, 10 – Valgeristi V, 11 – Valgeristi VI, 12 – Valgeristi VII, 13 – Valgeristi VIII, 14 – Inkatoa I, 15 – Küünimäe VI. The cyan colour denotes possible remnant freshwater bodies.

Kriiska & Lõugas 2009, fig. 36.5) than in the Late Mesolithic Narva stage sites (e.g. in the North-Estonian Vihasoo II and Kroodi sites in the range of 1–6%; Kriiska 1997, 9). This artefact typology suggests that the earliest settlement site is Kesu II at the confluence of the rivers Velise and Enge, featuring a high share of flint blades and probably pre-dating the LTM.

The majority of the newly discovered riverside sites (18) can be dated to the Comb Ware stage (Fig. 2) by a low share of flint blades and a high share of Carboniferous flint. Although Carboniferous flint is present in several Mesolithic

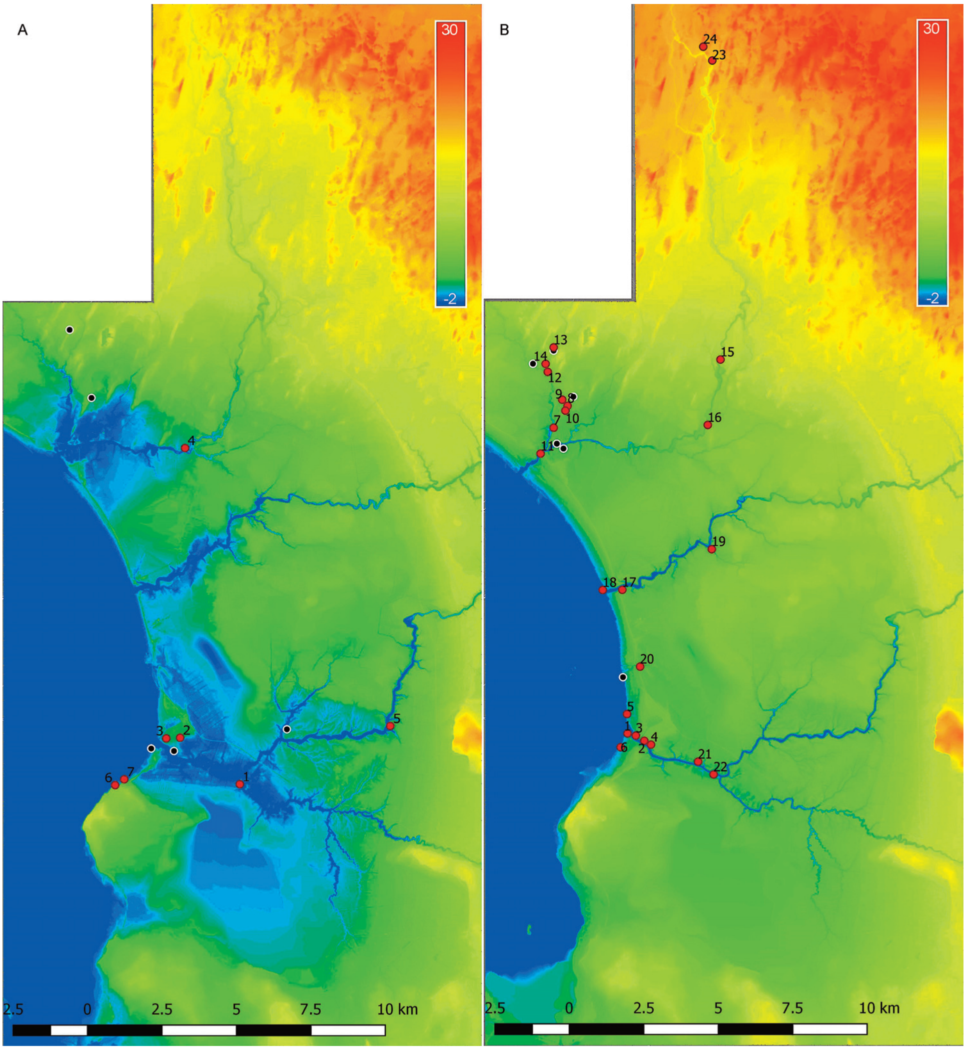

Fig. 8. Palaeogeographical reconstructions of the Teenuse–Ojapere–Avaste area, dating to 5300 BC (LTM, A) and 4000 BC (LTM, B), with settlement sites indicated by red and stray finds by black dots. The settlement sites A: 1 – Kesu II, 2 – Tõnumaa II, 3 – Tõnumaa I, 4 – Urevere I, 5 – Manni I, 6 – Avaste I, 7 – Avaste II; B: 1 – Ojapere I, 2 – Ojapere II, 3 – Ojapere III, 4 – Ojapere IV, 5 – Ojapere V, 6 – Ojapere VI, 7 – Teenuse II, 8 – Teenuse III, 9 – Teenuse IV, 10 – Teenuse V, 11 – Teenuse IX, 12 – Luiste I, 13 – Luiste II, 14 – Luiste III, 15 – Tolli I, 16 – Tolli II, 17 – Vana-Vigala I, 18 – Vana-Vigala II, 19 – Tiduvere, 20 – Oese I, 21 – Vanamõisa I, 22 – Kesu I, 23 – Sipa I, 24 – Sipa II.

settlement sites (e.g. Sander & Kriiska 2018, 77–78; Khrustaleva & Kriiska 2020, 41–42), the inflow of that material appears to have decreased significantly in most cases before the LTM. It reappeared as a typical material utilized by the people who used the Comb Ware pottery (Moora et al. 1935, 45–46; Jaanits 1959, 334;

Jaanits et al. 1982, 77; Kriiska 2015). However, the share of quartz finds could still exceed 90% of all lithic finds (e.g. Kadakas et al. 2010, 37; Khrustaleva et al. 2020, 55). The low diversity of finds at the settlement sites (very scarce pottery finds, wood chopping tools and evidence of stone grinding and polishing) is generally characteristic of the West Estonian Lowland beyond the study area of the current paper and can be interpreted as a marker of seasonality (Sander & Kriiska 2021).

As no remnant lakes were detected during the palaeogeographical reconstruction of the southern study area (Fig. 1: B), the most prominent factors shaping the settlement system should be considered the coastline, rivers and brooks. The sites datable to the Comb Ware stage can be divided into two groups: (1) the sites clustered by the River Velise in the Ojapere and Tõnumaa villages; (2) the aceramic sites by smaller streams. The presumably earlier Tõnumaa I–II aceramic sites are located near the coast of a barrier island of the Velise river-mouth lagoon at elevations higher than the LTM coastline (Fig. 8: A), each featuring some finds of

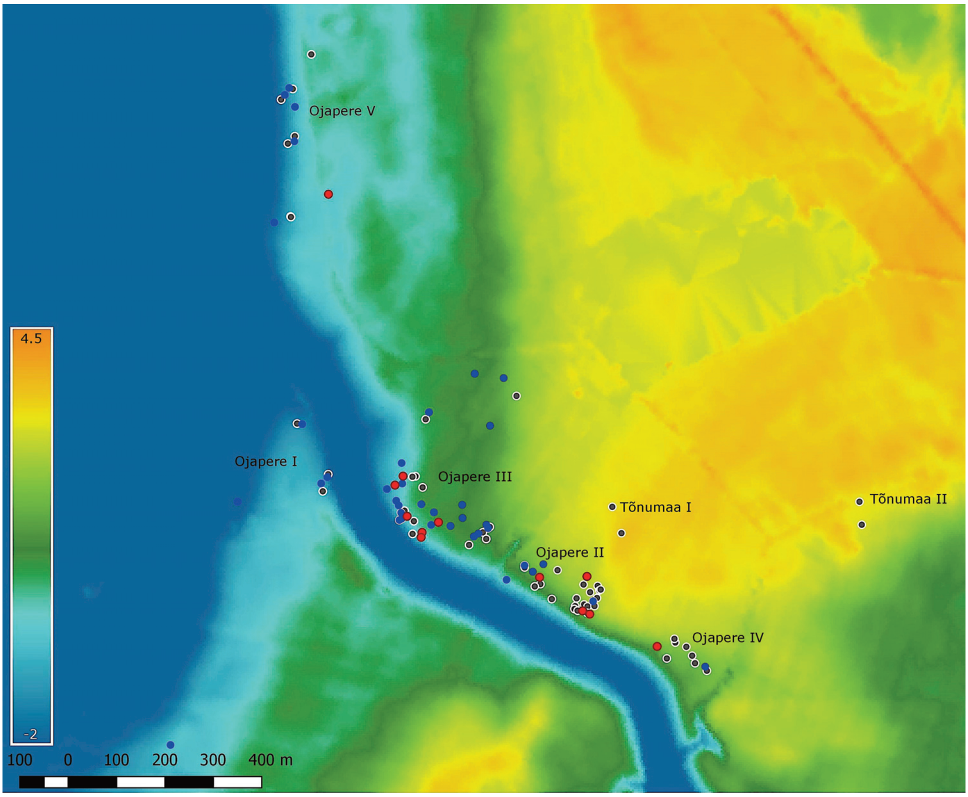

Fig. 9. Settlement sites in the Ojapere and Tõnumaa villages. Grey dots – Silurian flint, blue dots – Carboniferous flint, red dots – Comb Ware sherds. Finds of quartz and other lithic materials are excluded for clarity. The natural surface north of the Tõnumaa I site has been destroyed by mining.

Fig. 10. Present land use and settlement sites near Teenuse village. Blue dots – Carboniferous flint, grey dots – Silurian flint, white dots – quartz finds. The dashed cyan line denotes a former brook visible on the aerial photo provided by the Estonian Land Board. All the visible agricultural land was well observable and fieldwalked.

Silurian flint and quartz. At lower elevations, the Ojapere sites form a cluster with *tpq* values of coastal displacement chronology ranging from 5000 to 3400 BC (Sander & Kriiska 2021, Supp. table 1). While the Ojapere II and IV sites at higher elevations could have been used already during the Narva stage, no Narva Ware ceramic sherds have been found there, although Comb Ware sherds and Carboniferous flint finds are sparsely scattered over the whole area. However, the Silurian flint finds are more frequent at higher elevations and the Carboniferous flint finds at lower elevations (Fig. 9), similarly to the Massu IV island site in the Matsalu palaeobay (Sander & Kriiska 2021, 40–41, fig. 7), suggesting some human activity in the Narva stage. Similar intra-site dependence between the lithic materials used and the elevation of finds can be observed at Kunda Lammasmägi, but vice versa (artefacts of Carboniferous flint are more frequent among earlier finds; Sander 2014, 36–43).

While the large area (more than 13 hectares) and variable elevations of the Ojapere sites suggest seasonal use over a long period of time, the pattern of other riverside sites is radically different. The small areas of find clusters exclude the intensity similar to the mouth of the River Velise at Ojapere. For example, only four find clusters were discovered when fieldwalking more than 100 hectares of well-observable agricultural land north of Teenuse village (Fig. 10). The pattern of other presumably Comb Ware riverside sites (Fig. 8: B) is similar, an observation that is novel to the present work.

Although the 18 presumably Comb Ware settlement sites form about one third of all previously known Comb Ware sites of Estonia (Sikk et al. 2020), the number is still too small for seasonal locations changing yearly during the almost 2000-year Comb Ware stage (Fig. 2). Two alternative explanations for the observed pattern of aceramic riverside settlement sites deserve further attention. First, it is possible that the sites were used as an alternative to the Ojapere sites or some other yet unknown coastal cluster of similar size during brief periods of unfavourable conditions. However, the large area over which the sites are scattered (including two inland sites, Sipa I–II; Fig. 8: B, 23–24) makes the idea questionable. Secondly, this pattern might be a sign of the importance of these particular locations for small groups who returned to them year after year (persistent traditions of landscape use). This would be similar to the Narva and Comb Ware settlement phases at Kunda Lammasmägi, interpreted as seasonal by the authors of the current study because of the low number of ceramic finds (Sander & Kriiska 2018).

Conclusions

In areas with rapidly changing landscapes, such as coastal Estonia, palaeogeographical reconstructions of the coastline and freshwater bodies are essential for both archaeological prospection and interpretation of settlement patterns. The Digital Terrain Model provided by the Estonian Land Board together with the previously published data on isostatic land uplift enabled the reconstruction of palaeocoastlines, while The Digital Soil Map and the database of peatland studies including stratigraphically described sampling sites, made publicly available by the Estonian Land Board and Tallinn University of Technology, were used to reconstruct the mineral palaeosurface under organic sediments of the raised bogs and to verify possible remnant freshwater bodies behind the coastal formations.

Two case studies integrated palaeogeographical reconstructions of the Baltic Sea coastline and adjacent depressions under raised bogs with the results of archaeological prospection carried out in 2015–2017 and in 2020 (45 settlement sites and 18 stray find locations). The archaeological material can be dated to the late Pre-Pottery Mesolithic until ca 5200 BC, the Narva stage 5200–3900 BC and the Comb Ware stage 3900–1750 BC based on the lithic materials used, the lithic artefact typology (quantity of blades) and the clay vessel typology.

Three river-mouth palaeolagoons or estuaries were identified at the mouths of the rivers Vihterpalu, Teenuse and Velise. The coasts of the lagoons were actively used during the final part of the pre-pottery Mesolithic or the Narva stage. Two possible remnant palaeolakes were identified near the former mouth of the River Vihterpalu, deserving further study. Especially in the southern study area (Teenuse–Velise–Avaste), most of the discovered settlement sites can be dated to the Comb Ware stage and clustered along the freshwater streams of various sizes up to 10 km from the former river mouths. All the newly discovered settlement sites can be interpreted as seasonal due to the low diversity of the assemblages and the almost total lack of ceramic sherds.

The largest cluster of finds was discovered at the former mouth of the River Velise in the present Ojapere (Fig. 11) and Tõnumaa villages, covering more than 13 hectares and featuring a small number of Comb Ware and Corded Ware sherds among the finds. Other Comb Ware sites along smaller streams were aceramic and of rather small size. These are especially well-observable north of Teenuse village by the River Luiste and its tributaries, where an area of about 400 × 1200 metres

Fig. 11. View of the Ojapere II site on the right coast of the River Velise from the suspension bridge in Ojapere village. Further along the field, before the horizon of the trees in the middle of the picture, the Tõnumaa I–II sites are situated. Photo by A. Kriiska.

was surveyed, featuring three distinct find clusters. Such a settlement pattern could be interpreted as indicative of the importance of these particular locations for small groups who returned to them year after year (persistent traditions of landscape use). This observation is novel to the present work.

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References

Clark, J. G. D. 1936. The Mesolithic Settlement of Northern Europe. Cambridge University Press, Cambridge.

CloudCompare 2.10.2 Zephyrus. 2020. www.cloudcompare.org

Corradini, E., Groß, D., Wunderlich, T., Lübke, H., Wilken, D., Erkul, E., Schmölcke, U. & Rabbel, W. 2022. Finding Mesolithic sites: a multichannel ground-penetrating radar (GPR) investigation at the ancient Lake Duvensee. – Remote Sensing, 14: 3, 781. https://doi.org/10.3390/rs14030781

ESRI 1998. ESRI Shapefile Technical Description. An ESRI White Paper – July 1998. Environmental Systems Research Institute, New York.

Estonian Land Board 2017. Digital Soil Map. https://datadoi.ee/handle/33/103?show=full

Estonian Land Board 2021. Digital Terrain Model. https://geoportaal.maaamet.ee/eng/Maps-and-Data/Elevation-data/Download-Elevation-Data-p664.html

Europaeus, A. 1926. Stenålderskeramik från kustboplatser i Finland. – Nordiska Arkeologmötet i Helsingfors 1925. Ed. C. A. Nordman. (Suomen Muinaismuistoyhdistyksen Aikakauskirja, XXXVI: 1). Helsinki, 45–77.

Godwin, H. 1940. Post-glacial changes of relative land- and sea-level in the English Fenland. – Philosophical Transactions of The Royal Society of London. Series B: Biological Sciences, 570, 239–303.

Granlund, E. 1932. De svenska högmossarnas geologi: deras bildningsbetingelser, utvecklinghistoria och utbredning jämte sambandet mellan högmossebildning och försumpning. (Sveriges geologiska undersökning. Serie C: Avhandlingar och uppsatser, 373). Stockholm.

Grudzinska, I., Saarse, L., Vassiljev, J. & Heinsalu, A. 2013. Mid- and late-Holocene shoreline changes along the southern coast of the Gulf of Finland. – Bulletin of the Geological Society of Finland, 85: 1, 19–34. https://doi.org/10.17741/bgsf/85.1.002

Habicht, H.-L., Rosentau, A., Jõeleht, A., Heinsalu, A., Kriiska, A., Kohv, M., Hang, T. & Aunap, R. 2017. GIS-based multiproxy coastline reconstruction of the eastern Gulf of Riga, Baltic Sea, during the Stone Age. – Boreas, 46: 1, 83–99. https://doi.org/10.1111/bor.12157

Hang, T. & Miidel, A. 2008. Peipsi järve areng hilisjääajal ja pärast jääaega. – Peipsi. Eds J. Haberman, T. Timm, & A. Raukas. Eesti Loodusfoto, Tartu, 57–62.

Hang, E., Liblik, T. & Linkrus, E. 1964. On the relations between Estonian valley terraces and lake and sea levels in the Late-Glacial and Holocene periods. – Publications on Geography, IV. (Transactions of the Tartu State University, 156.) Tartu, 29–42.

Hang, T., Veski, S., Vassiljev, J., Poska, A., Kriiska, A. & Heinsalu, A. 2020. A new formal subdivision of the Holocene Series/Epoch in Estonia. – Estonian Journal of Earth Sciences, 69: 4, 269–280. https://doi.org/10.3176/earth.2020.15

Indreko, R. 1932. Kiviaja kronoloogia küsimusi. – Ajalooline Ajakiri, 4, 177–190.

Indreko, R. 1948. Die Mittlere Steinzeit in Estland. Mit einer Überschicht über die Geologie des Kunda-Sees von K. Orviku. (Kungl. Vitterheits Historie och Antikvitets Akademiens Handlingar, 66.) Wahlström & Widstrand, Stockholm.

Янитс, Л. Ю. 1959 = **Jaanits, L.** Поселения эпохи Неолита и раннего металла в приустье р. Эмайыги (Эстонская ССР). Академия наук Эстонской ССР, Таллинн.

Jaanits, L. 1961. Antropogeeni geoloogia osast arheoloogilistel uurimistel. – ENSV Teaduste Akadeemia Geoloogia Instituudi uurimused, VII. Eesti NSV Teaduste Akadeemia Geoloogia Instituut, Tallinn, 249–253.

Jaanits, K. & Ilomets, M. 1988. Umbusi mesoliitilise asula vanusest ja kohast Eesti keskmise kiviaja kronoloogias. – Loodusteaduslikke meetodeid Eesti arheoloogias. Artiklite kogumik. Eds A.-M. Rõuk & J. Selirand. Eesti NSV Teaduste Akadeemia Ajaloo Instituut, Tallinn, 54–64.

Jaanits, L., Laul, S., Lõugas, V. & Tõnisson, E. 1982. Eesti esiajalugu. Eesti Raamat, Tallinn.

Johanson, K., Kriiska, A., Aruväli, J., Somelar, P., Sikk, K. & Sepp, L. 2021. Local or imported? Tracking the provenance of flint raw materials of the Mesolithic habitants of Estonia and northern Latvia with the help of geochemical methods. – Foraging Assemblages, 1. Eds D. Borić, D. Antonović & B. Mihailović. Serbian Archaeological Society, Belgrade; The Italian Academy for Advanced Studies in America, Columbia University, New York, NY, 123–128.

Jussila, T. & Kriiska, A. 2004. Shore displacement chronology of the Estonian Stone Age. – Estonian Journal of Archaeology, 8: 1, 3–32.

Kadakas, U., Vedru, G., Lõugas, L., Hiie, S., Kihno, K., Kadakas, V., Püüa, G. & Toos, G. 2010. Rescue excavations of the Neolithic settlement site in Vabaduse Square. – AVE, 2009, 27–46.

Karukäpp, R., Moora, T. & Pirrus, R. 1996. Geological events determining the Stone Age environment of Kunda. – Coastal Estonia: Recent Advances in Environmental and Cultural History. Eds T. Hackens, S. Hicks, V. Lang, U. Miller & L. Saarse. (PACT 51.) PACT Belgium, Rixensart, 219–229.

Kessel, H. 1961. Balti mere arenemisest Eesti NSV territooriumil holotseenis. – ENSV Teaduste Akadeemia Geoloogia Instituudi uurimused, VII. Eesti NSV Teaduste Akadeemia Geoloogia Instituut, Tallinn, 167–186.

Khrustaleva, I. & Kriiska, A. 2020. Inside the dwelling: clay figurines of the Jägala Jõesuu V Stone Age settlement site (Estonia). – Baltic Journal of Art History, 20, 11–57. https://doi.org/10.12697/BJAH.2020.20.01

Khrustaleva, I., Roog, R., Kholkina, M. & Kriiska, A. 2020. Hunter-gatherer pit-houses in Stone Age Estonia. – Archaeological and Anthropological Sciences, 12, 56. https://doi.org/ 10.1007/s12520-020-01018-0

Kraft, J. C., Kayan, I. & Aschenbrenner, S. E. 1985. Geological studies of coastal change applied to archaeological settings. – Archaeological Geology. Eds G. Rapp, G. Jr. & J. A. Gifford. Yale University Press, New Haven, London, 57–84.

Kriiska, A. 1997. Kroodi ja Vihasoo III asula Eesti varaneoliitiliste kultuurirühmade kontekstis. – Estonian Journal of Archaeology, 1, 7–25.

Kriiska, A. 2001. Lääne-Eesti mandriosa kiviaja äärejooni. – Läänemaa muuseumi toimetised, V. Ed. Ü. Paras. Läänemaa Muuseum, Haapsalu, 7–40.

Kriiska, A. 2015. Foreign materials and artefacts in the 4th and 3rd millennia BCE Estonian Comb Ware complex. – When Gods Spoke. Researches and Reflections on Religious Phenomena and

Artefacts. Studia in honorem Tarmo Kulmar. Eds P. Espak, M. Läänemets & V. Sazonov. (Studia Orientalia Tartuensia, Series Nova, VI.) Tartu University Press, Tartu, 107–124.

Kriiska, A. & Lõugas, L. 2006. Scientific methods in Estonian archaeology. – Archaeological Research in Estonia 1865–2005. Eds V. Lang & M. Laneman. (Estonian Archaeology, 1.). Tartu University Press, Tartu, 269–291.

Kriiska, A. & Lõugas, L. 2009. Stone Age settlement sites on an environmentally sensitive coastal area along the lower reaches of the River Pärnu (south-western Estonia), as indicators of changing settlement patterns, technologies and economies. – Mesolithic Horizons. Papers Presented at the Seventh International Conference on the Mesolithic in Europe, Belfast 2005, I. Eds S. McCartan, R. Schulting, C. Warren & P. Woodman. Oxbow Books, Oxford, 167–175.

Kriiska, A., Johanson, K., Saluäär, U. & Lõugas, L. 2003. The results of research of Estonian Stone Age in 2002. – AVE, 2002, 25–41.

Kriiska, A., Johanson, K. & Khrustaleva, I. 2018. Checking the borders. Distribution of redeposited Silurian and Carboniferous flint in Estonia and Russia. – International conference "Crossing the Borders. Interregional and Cross-Cultural Interactions in the Context of Lithic Studies" (15th SKAM Lithic Workshop) 17–19 October 2018, Minsk. Abstract book. Eds V. Asheichyk, D. H. Werra, I. Sobkowiak-Tabaka, K. Pyżewicz & A. Vashanau. Stowarzyszenie Krzemieniarskie SKAM. Institute of History of the National Academy of Sciences of Belarus, Minsk, 37.

Kriiska, A., Lang, V., Mäesalu A., Tvauri A. & Valk, H. 2020. Eesti esiaeg. (Eesti ajalugu, I.) Tartu Ülikooli ajaloo- ja arheoloogia instituut, Tartu.

Laid, E. 1931. Kodumaa asustus muinasajal. – Eesti Kirjandus, 7, 353–367.

Lidén, R. 1938. Den senkvartära strandförskjutningens förlopp och kronologi i Ångermanland. – Geologiska Föreningen i Stockholm Förhandlingar, 60: 3, 397–404.

Lõugas, V. 1988. Loodusteaduslike meetodite kasutamisest Eesti arheoloogias. – Loodusteaduslikke meetodeid Eesti arheoloogias. Artiklite kogumik. Eds A.-M. Rõuk & J. Selirand. Eesti NSV Teaduste Akadeemia Ajaloo Instituut, Tallinn, 13–25.

Mägi, M. & Karro, K. 2015. Looduslikud olud praeguse Tallinna alal. – Mägi, M. Rafala. Idateest ja Tallinna algusest. Argo, Tallinn, 31–45.

Mandel, M. 1993. Läänemaa esiajalugu. Lääne Elu, Haapsalu.

Masing, V. 1988. Soode mõiste, levik ja väärtus. – Eesti sood. Ed. U. Valk. Valgus, Tallinn, 7–21.

Moora, H. 1934. Muinasaeg. – Saaremaa: maateaduslik, majanduslik ja ajalooline kirjeldus. Eds A. Luha, E. Blumfeldt & A. Tammekann. Eesti Kirjanduse Selts, Tartu, 244–262.

Moora, H. 1938. Muinasaeg. – Läänemaa: maateaduslik, majanduslik ja ajalooline kirjeldus. Üldosa. Eds H. Haberman, E. Kant, H. Kruus, A. Luha & A. Tammekann. Eesti Kirjanduse Selts, Tartu.

Moora, T. 1998. Muistsete loodusolude osast kiviaja asustuse kujunemisel Kunda ümbruses. – Loodus, inimene ja tehnoloogia. Interdistsiplinaarseid uurimusi arheoloogias Eds V. Lang & J. Peets. (MT, 5.) Ajaloo Instituut, Tallinn, 13–151.

Moora, T. & Moora, H. 1996. The ridge of Hiiemägi as a precondition for the formation of the ancient Lake Kunda. – Coastal Estonia. Recent Advances in Environmental and Cultural History. Eds T. Hackens, S. Hicks, V. Lang, U. Miller & L. Saarse. (PACT 51.) PACT Belgium, Rixensart, 231–240.

Moora, H., Laid, E., Mägiste J. & Kruus, H. 1935. Esiajalugu ja muistne vabadusvõitlus. (Eesti ajalugu, I.) Eesti Kirjanduse Selts, Tartu, 248–258.

Moora, T., Ilomets, M. & Jaanits, L. 1988. Muistsetest loodusoludest Akali kiviaja asulakoha lähiümbruses. – Loodusteaduslikke meetodeid Eesti arheoloogias. Artiklite kogumik. Eds A.-M. Rõuk & J. Selirand. Eesti NSV Teaduste Akadeemia Ajaloo Instituut, Tallinn, 26–38.

Moora, T., Reintam, L. & Jaanits, K. 1996. Environmental conditions in surroundings of Lammasmägi, Kunda. – Coastal Estonia. Recent Advances in Environmental and Cultural History. Eds T. Hackens, S. Hicks, V. Lang, U. Miller & L. Saarse. (PACT 51.) PACT Belgium, Rixensart, 239–251.

Moora, T., Raukas, A. & Tavast, E. 2002. Geological History of Lake Võrtsjärv. – Proceedings of the Estonian Academy of Sciences. Geology, 51: 3, 157–179.

Moora, T., Raukas, A. & Lõugas, L. 2016. Reo Kilbumäe ümbruse paleogeograafia ja Kõnnu neoliitiline asula. (Eesti Geograafia Seltsi aastaraamat, 41.) Eesti Geograafia Selts, Tallinn, 11–28.

Muru, M., Rosentau, A., Kriiska, A., Lõugas, L., Kadakas, U., Vassiljev, J., Saarse, L., Aunap, R., Küttim, L., Puusepp, L. & Kihno, K. 2017. Sea level changes and Neolithic hunter-fisher-gatherers in the centre of Tallinn, southern coast of the Gulf of Finland, Baltic Sea. – The Holocene, 27: 7, 917–928. https://doi.org/10.1177/0959683616678462

Muru, M., Rosentau, A., Preusser, F., Plado, J., Sibul, I., Jõeleht, A., Bjursäter, S., Aunap, R. & Kriiska, A. 2018. Reconstructing Holocene shore displacement and Stone Age palaeogeography from a foredune sequence on Ruhnu Island, Gulf of Riga, Baltic Sea. – Geomorphology, 303, 434–445. https://doi.org/10.1016/j.geomorph.2017.12.016

Nirgi, T., Rosentau, A., Ots, M., Vahur, S. & Kriiska, A. 2017. Buried amber finds in the coastal deposits of Saaremaa Island, eastern Baltic Sea – their sedimentary environment and possible use by Bronze Age islanders. – Boreas, 46: 4, 725–736. https://doi.org/10.1111/bor.12236

Nirgi, T., Rosentau, A., Habicht, H.-L., Hang, T., Jonuks, T., Jõeleht, A., Kihno, K., Kriiska, A., Mustasaar, M., Risberg, J., Suuroja, S., Talviste, P. & Tõnisson, H. 2020. Holocene relative shore-level changes and Stone Age palaeogeography of the Pärnu Bay area, eastern Baltic Sea. – The Holocene, 30: 1, 37–52. https://doi.org/10.1177/0959683619865603

Orru, M. 2020. Estonian Peat Database. https://turba.geoloogia.info

Orviku, K. 1936. Litoriina randvalli geoloogiast Kroodi oru kohal. – Eesti Loodus, 2, 61–63.

Orviku, K. 1948. Über die Geologie des Kunda-Sees. – Indreko, R. 1948, 17–39.

Orviku, K. 1973. Võrtsjärve geoloogilisest arengust. – Võrtsjärv. Ed. T. Timm. Valgus, Tallinn, 26–32.

Penu, P., Kikas, T., Suuster, E. & Astover, A. 2014. Suuremõõtkavalise digitaalse mullastikukaardi kvaliteedi ja rakendatavuse parandamine. – Mullastikukaartide- ja andmebaaside rakendused jätkusuutlikuks maakasutuseks ja põllumajandustootmiseks. Riikliku programmi lõpparuanne. Ed. A. Astover. Eesti Maaülikool, põllumajandus- ja keskkonnainstituut, Põllumajandusuuringute Keskus, Tartu, 4–14. https://www.pikk.ee/upload/files/Teadusinfo/Lopparuanne_Mullastikukaartide_Astover_pikk.pdf (last accessed 20.05.2021).

Pierik, H. J., Cohen, K. M. & Stouthamer, E. 2016. A new GIS approach for reconstructing and mapping dynamic late Holocene coastal plain paleogeography. – Geomorphology, 270, 55–70.

Pirazzoli, P. A. 1991. World Atlas of Holocene Sea-Level Changes. Elsevier, Amsterdam.

Quantum GIS 3.0.3 Girona. 2018. www.qgis.org

Raukas, A., Molodkov, A. & Tavast, E. 1999. Substantial lowering of the Ancylus Lake level as a precondition for human settlement around the Baltic Sea. – Environmental and Cultural History of the Eastern Baltic Region. Eds U. Miller, T. Hackens, V. Lang, A. Raukas & S. Hicks. (PACT, 57.) PACT Belgium, Rixensart, 89–104.

Rosentau, A., Veski, S., Kriiska, A., Aunap, R., Vassiljev, J., Saarse, L., Hang, T., Heinsalu, A. & Oja, T. 2011. Palaeogeographical model for the SW Estonian coastal zone of the Baltic Sea. – The Baltic Sea Basin. Eds J. Harff, S. Björck & P. Hoth. Springer, Berlin, 165–188.

Rosentau, A., Muru, M., Kriiska, A., Subetto, D., Vassiljev, J., Hang, T., Gerasimov, D., Nordqvist, K., Ludikova, A., Lõugas, L., Raig, H., Kihno, K., Aunap, R. & Letyka, N. 2013. Stone Age settlement and Holocene shore displacement in the Narva–Luga Klint Bay area, eastern Gulf of Finland. – Boreas, 42: 4, 912–931. https://doi.org/10.1111/bor.12004

Rosentau, A., Nirgi, T., Muru, M., Bjursäter, S., Hang, T., Preusser, F., Risberg, J., Sohar, K., Tõnisson, H. & Kriiska, A. 2020. Holocene relative shore level changes and Stone Age hunter-gatherers in Hiiumaa Island, eastern Baltic Sea. – Boreas, 49: 4, 799–812. https://doi.org/10.1111/bor.12452

Rõuk, A.-M. 1992. Interdisciplinary research on environmental history and archaeology. – Estonia: Nature, Man and Cultural Heritage. Proceedings of a Round Table held at Tallinn, April 1991 at the Estonian Academy of Sciences. Eds T. Hackens, V. Lang & U. Miller. (PACT, 37.) PACT Belgium, Rixensart, 51–61.

Rõuk, A. M. & Vuorela, I. 1992 = **Рыук, А. М. & Вуорела, И.** Связь древнего расселения с развитием Балтийского моря. – Геология Финского залива. Eds A. Raukas & H. Hyvärinen. Eesti Teaduste Akadeemia Geoloogia Instituut, Helsingi Ülikool, Tallinn, 328–354.

Saarse, L. 1994 = **Саарсе, Л.** Донные отложения малых озер Эстонии. Eesti Teaduste Akadeemia, Tallinn.

Saarse, L., Vassiljev, J. & Miidel, A. 2003. Simulation of the Baltic Sea shorelines in Estonia and neighbouring areas. – Journal of Coastal Research, 19: 2, 261–268.

Saarse, L., Vassiljev, J., Miidel, A. & Niinemets, E. 2006. Holocene buried organic sediments in Estonia. – Proceedings of the Estonian Academy of Sciences. Geology, 55: 4, 296–320.

Saarse, L., Vassiljev, J. & Rosentau, A. 2009a. Ancylus Lake and Litorina Sea transition on the Island of Saaremaa, Estonia: a pilot study. – Baltica, 22: 1, 51–62.

Saarse, L., Vassiljev, J. & Rosentau, A. 2009b. Litorina Sea shore displacement on the Island of Saaremaa, Estonia. – Polish Geological Institute Special Papers, 25, 59–66.

Sander, K. 2014. Kunda Lammasmäe kiviaja asulakoht. Master's thesis, University of Tartu, Tartu. https://dspace.ut.ee/handle/10062/41913

Sander, K. & Kriiska, A. 2018. New archaeological data and paleolandscape reconstructions of the basin of an Early and Middle Holocene lake near Kunda, north-eastern Estonia. – Fennoscandia Archaeologica, XXXV, 65–85.

Sander, K. & Kriiska, A. 2021.Archaeological traces of hunter-gatherer seasonal occupation in western coastal Estonia from the second half of the 6th millennium to the end of the 3rd millennium BC. Documenta Praehistorica, 48, 36–53. https://doi.org/10.4312/dp.48.24

SGU (Geological Survey of Sweden). 2021. Quarternary map viewers: Soil depth. www.sgu.se/en/products/maps/map-viewer/jordkartvisare/soil-depth

Shewchuk, J. R. 1996. Triangle: engineering a 2D quality mesh generator and Delaunay triangulator. – Applied Computational Geometry: Towards Geometric Engineering. Eds M. C. Lin & D. Manocha. (Lecture Notes in Computer Science, 1148.) Springer, Berlin, 203–222.

Shewchuk, J. R. 2002. Delaunay refinement algorithms for triangular mesh generation. – Computational Geometry: Theory and Applications, 22: 1–3, 21–74.

Siiriäinen, A. 1974. Studies relating to shore displacement and Stone Age chronology in Finland. (Helsingin yliopiston arkeologian laitos. Moniste, 10.) Helsingin yliopisto, Helsinki.

Sikk, K., Kriiska, A., Johanson, K., Sander, K. & Vindi, A. 2020. Environment and settlement location choice in Stone Age Estonia. – Estonian Journal of Archaeology, 24: 2, 89–140. https://doi.org/10.3176/arch.2020.2.01

Tallgren, A. M. 1922. Zur Archäologie Eestis, I. Vom Anfang der Besiedlung bis etwa 500 n. Chr. (Acta et Commentationes Universitatis Tartuensis (Dorpatensis), III: 6.) Dorpat.

Tvauri, A. & Johanson, K. 2006. Archaeological research on Kavastu Mesolithic and Early Modern settlement site in 2005. – AVE, 2002, 41–46.

Kristjan Sander ja Aivar Kriiska

GIS-PÕHINE LÄHENEMINE MUINASMAASTIKE REKONSTRUEERIMISELE NING ARHEOLOOGILINE LEIRE VIHTERPALU, TEENUSE JA VELISE KIVIAEGSETE JÕESUUDMELAGUUNIDE RANDADEL: INTEGREERITUD TULEMUS

Resümee

Paleo-siseveekogude, eriti praeguseks kadunud järvede kaldajoonte rekonstrueerimine erineb metoodiliselt muistse mere rannajoonte rekonstrueerimisest. Kui jõgede voolusängidest on digitaalsetel kõrgusmudelitel ja mullakaartidel selgemad jäljed, siis rabastunud muinasjärvede olemasolu või sügavuse kindlaks tegemine sõltub tavaliselt konkreetse märgala turbapadjandi uuritusest. Kunagise rannalähedase maastiku rekonstrueerimisel on oluline kontrollida, kas muistsete rannamoodustiste läheduses või vahel asuvad nõod võisid enne soostumise algust olla piisavalt sügavad, et mahutada arvestatavat püsiveekogu. Turbapadjandite teadaoleva tüsedusega arvestamine on mõtteka maastikurekonstruktsiooni eeldus ka sisemaal.

Maa-ameti kaardikihtide (digitaalne kõrgusmudel, mullakaart) ning Eesti turbauuringute andmebaasi andmed vajavad selleks töötlemist ning ühitamist, kuid on praeguseks hetkeks muutunud piisavalt täpseks, et nende põhjal kontrollida, kas hiljem turbapadjandite alla jäänud nõod olid pärast meretaseme alanemist piisavalt sügavad, et neisse võinuks moodustuda jäänukjärvi.

Käesoleva artikli uurimisalade kohta selgus, et Nõva muinaslahte suubuva Vihterpalu jõe suudmealale Keila-Haapsalu maanteest lõunas võis pärast jõesuudmelaguuni kadumist moodustuda üks-kaks hiljem rabastunud jäänukjärve, kuid sarnaselt rabastunud nõod Matsalu muinaslahe idakaldal Üdruma-Teenuse-Avaste piirkonnas on selleks liiga madalad. Võimalike jäänukjärvede asukohad väärivad detailsemat uurimist teistsuguste meetoditega.

Artiklis käsiteldav arheoloogiline leiumaterjal koguti leiretel osana Lääne-Eesti kiviaja uurimisel aastatel 2015−2017 ja 2020 tehtud suuremast tööst, mille tulemused on üldistatumal kujul avaldatud mujal. Artiklis esitatud uurimisaladelt avastati 45 kiviaegset asulakohta ning 18 leiukohta, millelt koguti peamiselt pinnakorje teel vastavalt 668 ning 23 arheoloogilist leidu. Kõiki asulakohti iseloomustab leiumaterjali üheülbalisus, mis seisneb keraamikaleidude, raieriistade ning lihvimiskivide puudumises või äärmiselt tagasihoidlikus hulgas, mistõttu on autorid neid tõlgendanud hooajalistena. Rohkete ja eranditult hooajalistena tõlgendatavate hilismesoliitiliste ning neoliitiliste asulakohtade avastamine suurel alal on uudne ning üllatav teaduslik tulemus kogu Läänemere idakalda jaoks. Lisaks leiti ka üks rohkete tulekivilaastudega arvatavasti Litoriinamere transgressioonimaksimumi eelne mesoliitiline asulakoht (Kesu II).

Kolm uuritud jõesuudmelaguuni (Vihterpalu, Teenuse, Velise) moodustusid enne Litoriinamere transgressioonimaksimumi ning kadusid V aastatuhande esimesel poolel eKr. Suurem osa Vihterpalu kunagises suudmes asunud laguuni ääres asuvatest asulakohtadest on Litoriinamere transgressioonimaksimumi aegsete rannamoodustiste vahetus läheduses, moodustades kaks selgelt eristuvat kobarat laguuni läänekaldal (Küünimäe asulakohad) ning laguuni Nõva muinaslahest eraldanud maaribal (Valgeristi asulakohad). Praegu on Vihterpalu jõesuudmelaguun ainus omalaadne Eestis, mille randadelt on avastatud tõenäoliselt keraamikaeelsest kiviajast pärinevaid asulakohti. Ainulaadne on ka nende asukoht sisemaaga piirneval rannaosal.

Üks asulakoht samast piirkonnast (Inkatoa I) pärineb tõenäoliselt hilisemast ajast, asudes Vihterpalu jõe ääres kunagise suudmelaguuni põhjal. Rannasiirdekronoloogia ning Karboni ladestu tulekivi puudumine leiumaterjalis lubavad Inkatoa I asulakohta dateerida Narva keraamika aega, kuigi savinõude kilde sealt ei leitud. Sarnaseid hilismesoliitilise ilmega (laastude vähesus, kvartsi rohkus, Karboni ladestu tulekivi puudumine) napi leiumaterjaliga asulakohti avastati ka tänapäeva Kasari jõe lisajõgede kallastel lõunapoolsel uurimisalal (Tõnumaa I–II, Oese I, Urevere I, Manni I) ning on varem leitud Kunda Lammasmäge ümbritsenud muinasjärve äärest, kus Karboni ladestu tulekivi esineb ka mesoliitilistes asulakohtades.

Suuremat osa tänapäeva Kasari jõe lisajõgede ääres asuvatest asulakohtadest (18) võib aga rohke Karboni ladestu tulekivi esinemise tõttu dateerida kammkeraamika staadiumi, kuigi kammkeraamika kilde leiti vaid mõnest kohast. Viimastest tõusevad kõige tähelepanuväärsematena esile asulakohad Velise jõe kallastel Ojapere ja Tõnumaa külade läheduses, millest kõrgemal asuvad pärinevad tõenäoliselt juba mesoliitikumist. Savinõukildude vähesuse tõttu kammkeraamika staadiumi dateeritavas leiumaterjalis võib Ojapere piirkonda võrrelda Kunda Lammasmäe asulakoha neoliitilise faasiga ning leiumaterjali rohkuse tõttu võib mõlemat pidada oma piirkonnas olulisteks hooajalisteks peatuspaikadeks.

Ülejäänud kammkeraamika staadiumi asulakohad Kasari jõe lisajõgede ääres erinevad Ojapere piirkonnast palju väiksema pindala ning keraamikaleidude täieliku puudumise poolest. Asulakohad olid leire käigus jälgitavad selgelt piiritletavate leiukogumitega, mis eriti hästi tuli välja Teenuse jõe ääres Teenusest põhjas, kus oli võimalik vaadelda üle 100 hektari üles küntud põldu, millelt leiti neli asulakohta. Selline asustusmuster ei sobitu hüpoteesiga, et jõekaldad olid kammkeraamika ajal pidevas kasutuses ning igal aastal peatuti juhuslikult välja valitud kohas, sest sel juhul peaks ala olema kammkeraamika aja leidudega üle külvatud. Leiukogumite moodustumisel on kaks võimalikku seletust: need kas deponeeriti lühiajaliste asulakohtade kasutamise ajal mõne erandliku sündmuse puhul, mis ei võimaldanud tavapärast maakasutust kusagil mujal (näiteks kõrge veeseis Velise jõe ääres Ojapere küla lähistel) või need on märgid püsivate traditsioonidega maastikukasutusest (aasta-aastalt pöörduti tagasi ühele ja samale kohale võrreldavalt Kunda Lammasmäega). Kõnealuste asulakohtade leviku suure pindalalise ulatuse tõttu peavad autorid tõepärasemaks viimast.