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CONTENTS

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CHRONOLOGY AND SETTLEMENT AT BARTSGÅRDA ON ÅLAND

Abstract

This article publishes a full series of 55 radiocarbon dates from the settlement and cemetery site at Bartsgårda on the Åland Islands, shedding new light on its chronology and use. During four years of investigations by the University of Helsinki field school from 2020 to 2023, small-scale excavations were conducted on different parts of the settlement area, revealing that the site, initially identified as belonging to the Nordic Late Iron Age (AD 550–1050), has a much longer occupation history extending back to the Late Bronze Age. The dates from the Late Iron Age houses are further analysed using Bayesian statistics, providing an argument for a sequential establishment of the structures, with the most intense settlement occurring between AD 750–950. Our study also provides insights into the socio-economic and cultural dynamics at Bartsgårda by discussing the nature, function, and chronology of the investigated archaeological contexts.

Keywords: radiocarbon dating, settlement archaeology, Bronze Age, Iron Age, Middle Age, Åland

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INTRODUCTION

The site of Bartsgårda (site ID Fi 2.1), in the parish of Finström, situated centrally in the Åland Islands, was first identified, and mapped in the very beginning of the last century by Björn Cederhvarf and Hugo Sommarström (Fig. 1), in the pioneering days of archaeology on the islands. The site was 'rediscovered' in the archives (see for details Ilves & Perttola 2020) and chosen as a location for the University of Helsinki field school excavations in 2020–2023 conducted in the framework of the Research Council of Finland's research project (332396). The site consists of a large Nordic Late Iron Age (AD 550–1050) burial ground with 110 grave mounds, mainly round stone cairns covered by a sandy mound erected on top of the cremation burials, and an adjacent settlement area with remains of so-called stone foundation houses still partially visible in the landscape. Stone foundation houses, mostly rectangular, three-aisled structures built with roof-supporting posts, were constructed with low dry-stone walls set on the outside of an inner wood-wall

structure. Houses with stone foundations are also known from other Baltic islands, notably Gotland and Öland in Sweden, as well as from some parts of Norway. However, they mainly date to an earlier period (c. AD 200–700) and differ significantly in construction from the stone frames found around Ålandic houses (cf. Carlsson 1979; Fallgren 2006; Svedjemo 2014). During the Late Iron Age, stone foundation houses were characteristic of the Åland Islands; however, post-built houses from the same period, though less commonly identified, have also been documented on Åland (Ilves 2018; Rosberg 2024).

A notable aspect of the site at Bartsgårda is the discernible number of features indicating stone foundation house remains. Unlike the scattered, single farmsteads typically found in the Late Iron Age Åland Islands – often characterised by only few buildings (Ilves 2018, Table 1) – the Bartsgårda settlement features over 30 potential houses, thereby being the largest site by the number of houses documented on Åland. The houses are clustered in complexes east and northeast of the burial mound area (Fig. 1). Unfortunately, the site as a whole was largely forgotten due to insufficient documentation and lack of subsequent analysis following its initial discovery and investigations. The official register of ancient monuments on Åland lists only five stone foundation houses at Bartsgårda (see also Karlsson 1987: 8).

The perception of Åland during the Late Iron Age is strongly characterised by the idea of single farms, a view challenged among other things by sites with multiple house foundations. When the archaeological site in Bartsgårda was rediscovered, it could already be noted before the excavations began that a large portion of the previously mapped house foundations could still be observed with the naked eye through stone rows in the landscape, sometimes in the form of

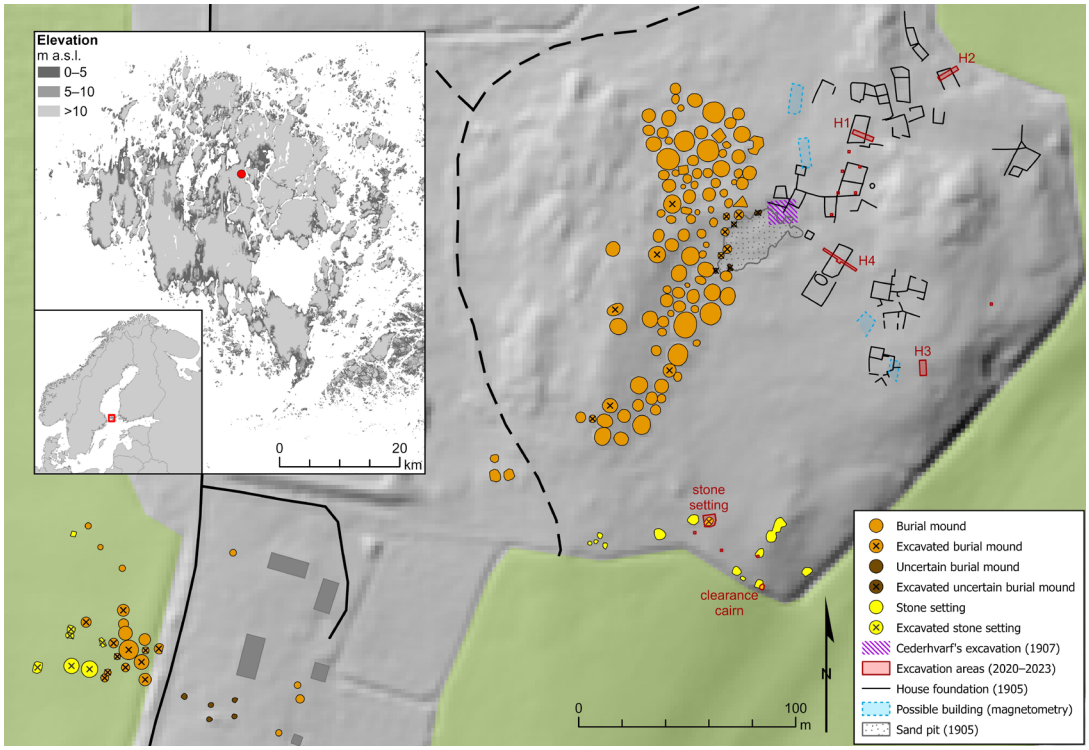

Figure 1. Location of Bartsgårda in the central part of the Åland Islands. The site map of Fi 2.1 and Fi 2.2 displays the archaeological features and the location of the excavated areas. Contains data from the National Land Survey of Finland elevation models 2 m and 10 m, topographic map 1:100 000, and topographic database (11/2024). Maps: K. Ilves and W. Perttola.

Table 1. Radiocarbon dating results of the Bartsgårda site. Radiocarbon dates are calibrated with software program IOSACal: v0.4.0 using the IntCal20 atmospheric curve (Reimer et al. 2020).

Context	Layer/feature	Excavation unit	Material	Laboratory number	14C age BP	SD 1σ	Cal 2 sigma	Reference
Grave 49			nutshell	Ua-62403	1237	31	AD 680 - 880	Ilves et al. fortcoming
Fireplace	under the structure		bark	Ua-62406	589	30	AD 1290 - 1420	This article
House 1	3	201.0/505.0	nutshell	Ua-68765	1346	29	AD 645 - 772	Holmqvist & Ilves 2022a
	5	200.0/501.0	nutshell	Ua-68768	1227	29	AD 686 - 884	Holmqvist & Ilves 2022a
	4	200.0/504.0	indet. cereal	Ua-68771	1147	30	AD 776 - 989	Holmqvist & Ilves 2022a
	3	201.5/504.5	nutshell	Ua-68766	1140	28	AD 776 - 991	Holmqvist & Ilves 2022a
	6	201.5/503.5	nutshell	Ua-68769	1138	29	AD 776 - 991	Holmqvist & Ilves 2022a
	pit	A005	nutshell	Ua-68764	1118	28	AD 776 - 993	Holmqvist & Ilves 2022a
	4	200.5/500.5	nutshell	Ua-68770	1105	30	AD 886 - 1016	Holmqvist & Ilves 2022a
	5	201.5/505.5	nutshell	Ua-68767	1081	29	AD 893 - 1021	Holmqvist & Ilves 2022a
	vertical sample 27	through A009	wheat	Ua-71486	1278	29	AD 664 - 820	This article
	vertical sample 23	through A009	wheat	Ua-71483	1223	29	AD 687 - 886	This article
	vertical sample 24	through A009	wheat	Ua-71484	1181	29	AD 774 - 972	This article
	vertical sample 26	through A009	wheat	Ua-71485	1170	29	AD 775 - 974	This article
	vertical sample 22	through A009	wheat	Ua-71482	1116	29	AD 776 - 994	This article
House 2	pit	A002	charcoal (hazel)	Ua-72575	2460	27	754 - 416 BC	This article
	5	401.0/807.5	nutshell	Ua-71866	1741	29	AD 245 - 402	This article
	posthole	A004	charred excrement	Ua-72572	1350	26	AD 645 - 772	Holmqvist & Ilves 2022a
	floor	K04	charcoal (birch)	Ua-72577	1338	27	AD 649 - 772	Holmqvist & Ilves 2022a
	posthole	A003	charcoal (spruce)	Ua-72576	1334	27	AD 651 - 772	Holmqvist & Ilves 2022a
	pit	A002	charcoal (birch)	Ua-72574	1317	26	AD 656 - 773	Holmqvist & Ilves 2022a
	4	400.0/809.5	nutshell	Ua-71864	1305	30	AD 659 - 773	Holmqvist & Ilves 2022a
	posthole	A001	charcoal (birch)	Ua-72573	1290	26	AD 667 - 773	Holmqvist & Ilves 2022a
	4	401.5/803.0	nutshell	Ua-71867	1165	30	AD 775 - 975	Holmqvist & Ilves 2022a
	2	401.0/804.0	indet. seed	Ua-71865	1152	31	AD 775 - 989	Holmqvist & Ilves 2022a
House 3	6	203.5 / 501.5	nutshell	Ua-77100	1728	30	AD 249 - 406	This article
	3	201.0 / 502.5	indet. organic	Ua-77106	1715	30	AD 251 - 413	This article
	5	204.0 / 500.5	nutshell	Ua-77101	1238	29	AD 680 - 881	This article
	3	204.5 / 501.5	nutshell	Ua-77102	1213	29	AD 692 - 889	This article
	4	205.5 / 500.5	nutshell	Ua-77103	1213	30	AD 690 - 890	This article
	4	205.5 / 502.5	nutshell	Ua-77104	1210	30	AD 690 - 891	This article
	5	206.5 / 500.5	nutshell	Ua-77105	1176	30	AD 775 - 973	This article
House 4	2	301.0 / 602.0	nutshell	Ua-80910	2628	30	829 - 773 BC	This article
	6	301.5 / 609.5	nutshell	Ua-80916	1251	36	AD 672 - 877	This article
	4	301.5 / 609.0	nutshell	Ua-80912	1233	29	AD 683 - 882	This article
	pit	A008	rye	Ua-80918	1226	32	AD 683 - 886	This article
	5	301.0 / 608.5	nutshell	Ua-80915	1219	29	AD 689 - 887	This article
	8	301.5 / 607.0	nutshell	Ua-80917	1218	29	AD 690 - 887	This article
	2	301.5 / 607.0	nutshell	Ua-80911	1196	29	AD 707 - 947	This article
	posthole	A004	nutshell	Ua-80909	1191	29	AD 709 - 949	This article
	5	301.5 / 612.5	nutshell	Ua-80913	1190	29	AD 709 - 951	This article
	5	301.0 / 617.5	nutshell	Ua-80914	1179	29	AD 774 - 972	This article
	posthole	A009	rye	Ua-80919	1139	38	AD 775 - 993	This article

Stone setting	cairn - under		flax	Ua-76442	2506	31	778 - 520 BC	Vanhanen & Ilves 2025
	fireplace		charcoal	Ua-81533	2473	31	767 - 422 BC	This article
	wall		nutshell	Ua-81525	2468	30	760 - 420 BC	This article
	wall		indet. herb	Ua-81526	2421	31	747 - 401 BC	This article
	cairn - middle		indet. herb	Ua-81531	2382	30	715 - 393 BC	This article
	floor - under		indet. cereal	Ua-76441	2370	30	539 - 390 BC	This article
	cairn - outside		wheat	Ua-81530	1124	29	AD 776 - 993	This article
	posthole		indet. cereal	Ua-81532	1072	29	AD 894 - 1024	This article
	cairn - top		horsetail	Ua-81528	912	29	AD 1040 - 1212	This article
	wall - top		horsetail	Ua-81529	912	29	AD 1040 - 1212	This article

lines or L-shapes, but also complete rectangles. In 2020 the University of Helsinki initiated its field-school excavations at Bartsgårda with the aim of determining whether the stone rows next to one of the largest[1] Late Iron Age burial fields in Åland belong to houses contemporary with the cemetery, and how they relate to each other in terms of both time and function. As part of the broader investigations at Bartsgårda, small-scale excavation trenches were opened on four house foundations. In addition, the entire archaeological area has been mapped and examined using both terrestrial laser scanning (Ilves & Perttola 2020) and magnetic prospection (Messal & Ilves 2022), and test pit excavations have also been conducted. Furthermore, following the surveys at the site – that were inspired by the first radiocarbon dating results pointing towards much longer settlement history of this landscape – excavations were also conducted on two newly discovered stone settings at the edge of the surviving settlement area.

This article presents the key results from the field investigations in Bartsgårda, with a primary focus on publishing and analysing the complete series of 55 radiocarbon dates (see Table 1), all processed in the Tandem Laboratory at Uppsala University[2], to establish a refined chronological framework for the site's multi-period occupation. We also discuss the nature of the settlement with a special focus on the Late Iron Age, while contextualising this phase within both the preceding and subsequent periods, starting with the Late Bronze Age and ending in the medieval period. For the Late Iron Age, we further propose a more detailed theory of settlement growth and its possible demographic, economic, and societal drivers, as well as variations in house functions, abandonment processes, and the formation of house remains in a comparative regional perspective.

FIRST INVESTIGATIONS

When the archaeological complex at Bartsgårda was first noted by Cederhvarf, he also conducted excavations at the site, focusing primarily on areas near the sand pit that had caused damage to the archaeological remains; this sand pit has since grown in scope. During the years 1905, 1906, and 1909, 14 graves[3] and one house foundation were investigated. Unfortunately, no excavation reports of these investigations were produced, though find catalogues (NM 4629, NM 4780, and NM 5388) are available. These catalogues reveal that the finds from the excavated graves include typical grave goods commonly encountered in Late Iron Age cemeteries on Åland (e.g., Kivikoski 1963; 1980). Based on the presence of several diagnostic jewellery items in some of the graves, the burial field has been dated from the Merovingian period to the end of the Viking Age, i.e. to the Late Iron Age. One of the investigated graves, mound no. 49, which contained a so-called clay paw burial (Ilves 2019a; Ilves et al. forthcoming), has been since radiocarbon dated to calAD 680–880 (Ua-62403, Table 1).

Based on the site drawing (Fig. 2) and notes in the relevant find catalogue (NM 5388), Cederhvarf's study of the settlement remains by the sand pit uncovered a section of an east-west-oriented stone wall and 17 possible postholes,

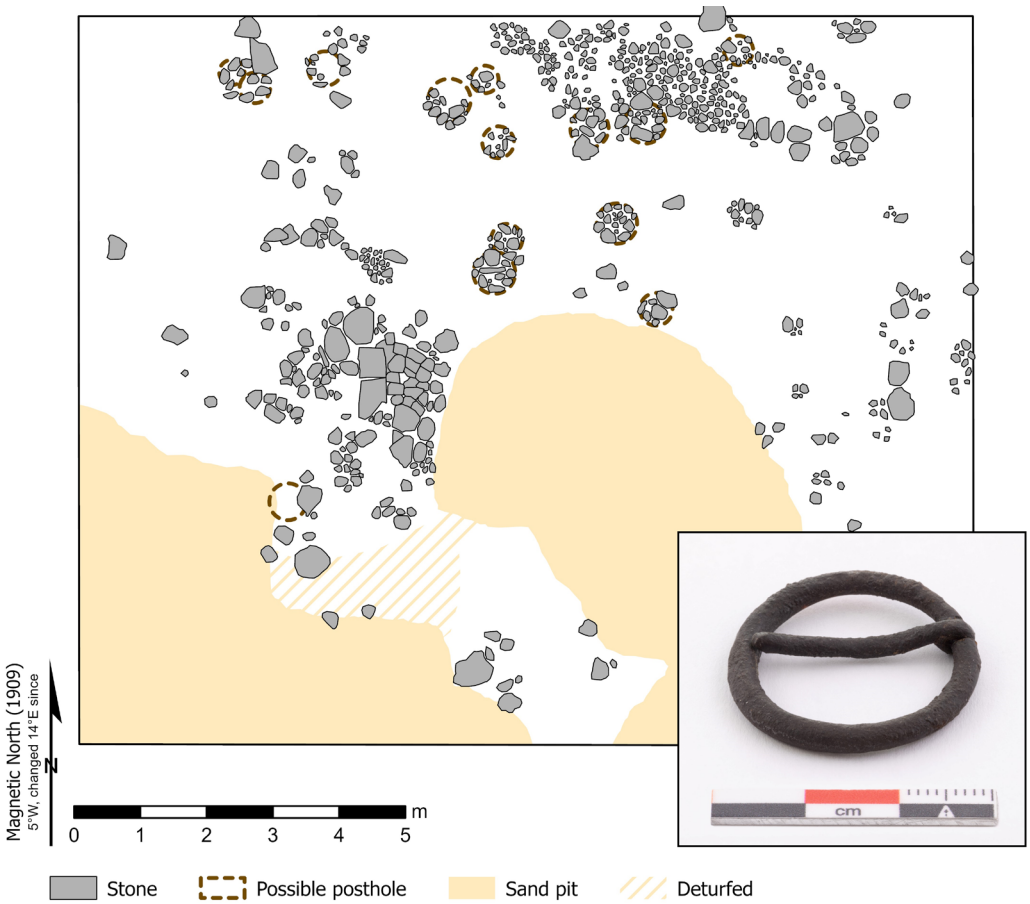

Figure 2. Digitalised version of the plan drawing from Björn Cederhvarf's excavation of the settlement remains by the sand pit. Inset: A copper-alloy ring brooch dated to the 12-15th centuries discovered near the rectangular hearth feature. Map: K. Ilves and W. Perttola, photo: W. Perttola.

some of which were associated with the wall. Within the excavated area, the postholes do not form an obvious structural pattern, such as roof-supporting post pairs, but the remains still suggest that the investigations involved a house remain. Among the documented features was a well-constructed rectangular hearth, at the edge of which, beneath one of the larger hearth stones, a ring brooch was discovered (Fig. 2 inset).

The brooch, in good condition, has a closed, undecorated circular frame with a fixed pin. Such brooches are characteristic of the Middle Ages and widespread geographically and chronologically, with a high find frequency and parallels dating broadly from the 1100s to the 1400s (Søvsø 2009). Other finds from the house excavation include osteological material, which was not analysed, along with burnt clay from wattle-and-daub constructions as well as loom weights and/or net weights, ceramics, fragments of knives, nails and rivets, slag, whetstones, and flint. These artefacts are generally undiagnostic and commonly found in Late Iron Age settlement contexts. The section of the settlement area examined by Cederhvarf was temporally defined as Late Iron Age based on its location adjacent to the cemetery, the composition of finds, and the nature of the documented construction features. However,

the ring brooch indicates a medieval usage phase in the area, a conclusion later confirmed by radiocarbon dating of a piece of bark collected during Cederhvarf's investigations. This sample, taken from beneath and connected to another rectangular hearth feature near the sand pit, was dated to calAD 1290–1420 (Ua-62406, Table 1).

The initial investigations at Bartsgårda, both in the cemetery and settlement areas, also uncovered a number of lithic (rhyolite) flakes typical of Ålandic Stone Age sites. Since these parts of the site at Bartsgårda are situated over 30 metres above sea level, post-glacial isostatic land uplift – which is part of the broader phenomenon of shoreline displacement, gradually raising the land and creating distinct ancient shorelines corresponding to different time periods – would have made the investigated area gradually available for habitation between c. 2500–2000 BC, i.e., at the end of the Stone Age. This pointed at a topographical possibility of an earlier settlement phase in the area, although this possibility was not explicitly considered during the early investigations. Overall, the findings from the initial work by Cederhvarf suggested that the area was occupied during multiple time periods. Consequently, one of the key objectives of the new fieldwork was to clarify and refine the chronology of Bartsgårda.

INVESTIGATIONS IN 2020–23

During the investigations in 2020–23, in total 120 m² was excavated, which constitutes just a small fraction of the size of this settlement. The area with visible stone foundation houses alone extends over at least 1.3 hectares. Excavations were conducted manually. In the investigation of the houses, a different building was examined each year, but the same methods were applied during all field seasons. Investigation areas measuring 20–21 m² were systematically placed perpendicular to house-like features, crossing the walls in order to examine both the interior and exterior contexts of the structures. All buildings were thus excavated only partially – just 10 m² (Houses 3 and 4) and 15 m² (Houses 1 and 2) of the houses themselves were studied. Trenches were divided into 1-by-1 m squares and then into 50-by-50 cm quadrants; after removing the about 5 cm thick turf layer, they were excavated in 5 cm mechanical layers until the natural soil layers, after which the remaining feature bottoms, postholes, pits, and ditches were excavated contextually. Samples for radiocarbon dating, mainly from short-lived materials, such as hazelnut shells, cereal grains, and other macrofossils, were collected from various investigation levels, units, and features in order to capture as much as possible the entire stratigraphy as well as different parts of the investigation areas. Short-lived materials were prioritised because they provide more accurate estimates for the deposition age. Ten test-pits, one square meter each, all testifying to the traces of settlement, were also excavated in mechanical layers; no radiocarbon analyses were conducted on the material from these contexts. The stone settings were excavated following similar general principles, although both of these visible features were studied entirely and samples for radiocarbon dating were collected based on the defined contexts / features rather than stratigraphy.

House 1

The first house examined, House 1 (Ilves 2021), like the other houses investigated, turned out to be undisturbed by modern activities. The investigation indicated that House 1 had been used as a dwelling for an extended period. It shows signs of several usage phases: renovations and traces of maintenance of roof-supporting structures, as well as at least one fire episode after which the house continued to be used (Holmqvist & Ilves 2022a). The construction of House 1 – a three-aisled house with a central roof-supporting pairs of posts that has an outer wall built with a single row of larger boulders placed on the ground surface and facing the outside of the building, with a packing of smaller stones inside supporting the inner wooden wall of the house (Fig. 3) – closely resembles previously examined stone house foundations on Åland (e.g., Hackman 1940; Kivikoski 1946; Dreijer 1955). At the same time, the investigation pointed to the possibility that there may have been a post-built structure on the site prior to the construction of a stone foundation house, or that one long side of the building may have initially

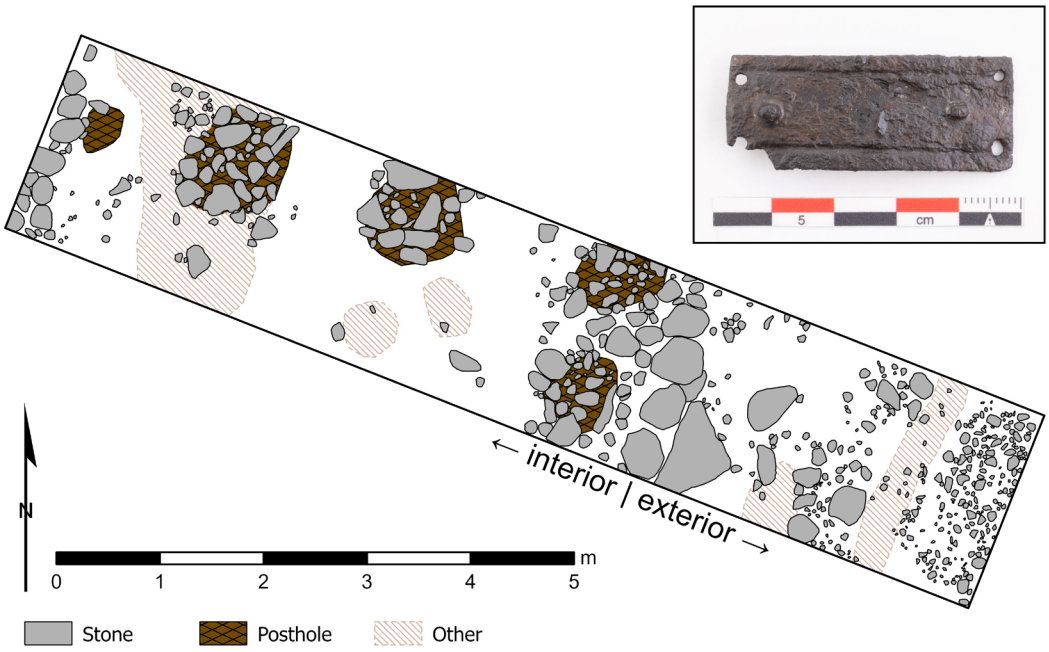

Figure 3. House 1 with its postholes and an indication of the interior and exterior areas separated by the stone wall; stones represent mechanical layer 3. Inset: An unusual rectangular iron brooch discovered in the house. Map: K. Ilves and W. Perttola, photo: W. Perttola.

been post-built. Furthermore, it became clear that the area examined outside the stone frame itself had also been actively used.

A large number of varied finds were uncovered from House 1, ranging from a rich osteological (3 kg) and macrofossil material (including 32 identified plant taxa) to artefacts such as tools, equipment, and jewellery. The osteological analysis (Kangasmaa 2021) established a high species diversity. Among the identified domesticated mammals were sheep/goat, cattle, and pigs; from wild mammals, in addition to forest hare, three different seal species were identified: grey seal, ringed seal, and harbour seal. There is also a significant variation among represented bird species, especially of waterbirds, while fishing was dominated by perch and pike. Macrofossil analysis of a remarkably rich record (Lempiäinen-Avci 2021) confirmed the subsistence strategy including cultivars such as rye, wheat, oats, and flax, but also wild species such as raspberries and hazelnuts. Among the noteworthy artefact finds of the investigation is a gilded pendant from the 10th century (Holmqvist & Ilves 2022b; Ilves 2025), as well as an unusual rectangular iron brooch with small holes in the corners and a simple decoration of raised knobs and running lines along the edges (Fig. 3 inset).

House 1 was radiocarbon dated with 13 samples from the second half of the Merovingian period to the end of the Viking Age, to calAD 645–1021 (Ua-68764, 68765, 68766, 68767, 68768, 68769, 68770, 68771, 71482, 71483, 71484, 71485, 71486, Table 1). All of the samples come from the areas and features related to the house structure and no radiocarbon dating was carried out in relation to the area outside. As the house has a thick cultural layer and signs of several usage phases, an attempt at a targeted vertical dating of the building and related activities was designed. Five cereal grains of wheat were analysed from vertical column samples of soil taken through different layers and through the ditch feature inside the house, but the radiocarbon dating proved unsuitable in resolution, as the date ranges of the samples largely overlapped and did not allow discussion on the stratigraphic order of the deposits (see also Table 1).

House 2

House 2 (Ilves 2022) was located on the outer area in relation to most of the stone foundation house features of the site; approximately 40 m east of House 1 and on the lower-lying part of the settlement (see also Fig. 1), at 25 metres above sea level. The investigation encompassed a continuous area of 20 m² and verified that this feature was indeed a house foundation, although the construction of the building deviates somewhat from previously known house foundations on Åland. House 2 differs due to the construction of the outer wall, which appears unusually complex compared to the norm of a simple row of larger stones laid at ground level. The wall of this building was raised on top of the layer of even-sized smaller stones and was built with two parallel rows of larger boulders, spaced apart from each other, facing the outside of the building; there is an interior packing of smaller stones in connection with the inner row of boulders (Fig. 4). It is also notable and unusual that the house appears to have had a longitudinal division.

The find material from House 2 is sparse and characterised by little variation – primarily consisting of mostly undecorated Iron Age ceramics (1.6 kg), but includes a few diagnostic finds in the form of beads, such as a so-called 'Ribe-type' bead, the production period of which is dated to AD 710–760, and a worn-out faceted carnelian bead of Oriental origin dated to the end of the 9th century and the 10th century (Fig. 4 inset; see closer Ilves 2025). Both the osteological and macrofossil material in House 2 were also very scarce (Vanhanen 2022), only 0.4 kg of highly fragmented bones were recovered,

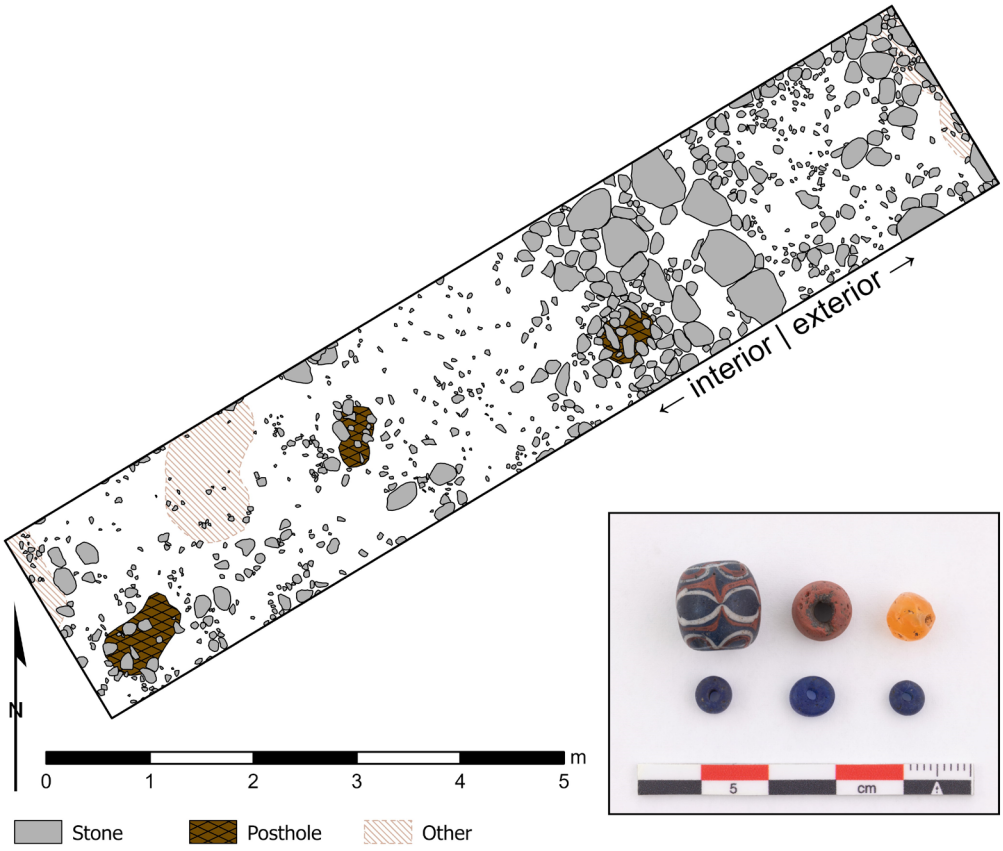

Figure 4. House 2 with its postholes and an indication of the interior and exterior areas separated by the stone wall; stones represent mechanical layer 4. Inset: Beads discovered in the house. Map: K. Ilves and W. Perttola, photo: W. Perttola.

and just one cultivated cereal grain was identified. This collectively indicates that food was neither prepared nor stored in the building, although it is also possible that any residue was meticulously cleaned out (Holmqvist & Ilves 2022a). Although the house had several activity phases evidenced by a central posthole with signs of the post being replaced at least once and renewed floor layers, it had a clearly different function(s) not connected to subsistence and domestic behaviour, but possibly to ritual activities (see closer Holmqvist & Ilves 2022a). In its final phase, part of the inside of House 2 had been intentionally "sealed" with a thin and uneven layer of heavily burned, though not sooty stones – this layer was exposed directly under the turf. The unexpected and unparalleled find of a large, flat snow-white limestone slab measuring about 40 by 50 cm and 10 cm in height (Holmqvist & Ilves 2022a: fig. 3B), with its underside covered with red substance, most probably ochre, inserted into the otherwise granite and sandstone constructed wall of the house, further indicated ritual activities and meanings connected with this building.

House 2 was radiocarbon dated with 10 samples (Table 1): eight came from the areas and features related to the house, one from underneath the outer wall construction, and one from an artificial ridge-like feature from the area outside the building. Eight samples, including the one from outside the building, were dated to calAD 645–989 (Ua-72572, 72573, 72574, 72576, 72577, 71864, 71865, 71867), i.e. roughly to the same period as House 1. There were however two samples that provided somewhat unexpected results – the sample from underneath the outer wall dated to the Roman Iron Age, calAD 245–402 (Ua-71866), and the second sample from the bottom of a large pit feature dated to the end of the Bronze Age and beginning of the Early Iron Age, to 754–416 calBC (Ua-72575).

House 3

The focus of the 2022 excavations was an area deliberately selected due to the absence of visible house foundation remains. The excavation trench was located approximately 10 metres east of the area where Cederhvarf documented stone rows and where the geophysical surveys conducted in the previous year had indicated the presence of additional house features (see also Fig. 1). However, the 21 m² excavation trench indeed also turned out to be on top of a Late Iron Age house, House 3 (Ilves et al. 2024). These results, when considered alongside the magnetic prospection and test pit excavations, demonstrate that building remains at Bartsgårda are present even in areas lacking visible surface features today or during Cederhvarf's times.

The outer wall of House 3 is of different type compared to Houses 1 and 2. It consists of a sparse row of really large stones with somewhat smaller stones between and adjacent to these, primarily on the inside of the house (Fig. 5). Although only a 3-metre-long segment of the wall was examined, it can be stated that at least one of the larger stone blocks in the wall is in its natural position. Another large block had been placed on its edge on a layer of smaller stones – this block has also served as a stationary grinding stone with the grinding surface facing the inside of the house. The house placement has utilised the local topography by being positioned on the edge of a naturally terraced slope; the examined outer wall marked the transition to a lower-lying terracing where only a few finds were made. The house itself contained a large quantity of varied finds. The osteological record, 4.4 kg in total, is diverse (Gómez Kobayashi 2023) as is the macrofossil material (Leppäsalko & Vanhanen 2023); the analysis of both have expanded the list of identified taxa at the site (see above, House 1), adding horse, several fish species (such as pike-perch, ide, eel, whitefish, carp, and roach), more birds including black grouse, little jay, and coot, as well as new plants like gold-of-pleasure and dog rose. The number of artefacts recovered from the house is substantial, especially considering the limited size of the excavation area. In addition to common settlement finds, such as the coarse domestic pottery (4.6 kg), the house yielded a considerable number of metal tools and artefacts, among which there are seven worn-out fragments of different Samanid dirhems from the beginning and middle of the 10th century (Fig. 5 inset)[4], and large number (22) of beads, including distinctly diagnostic specimens that originate from the domination of the Samanids in Central Asia and dated to the late 10th and the

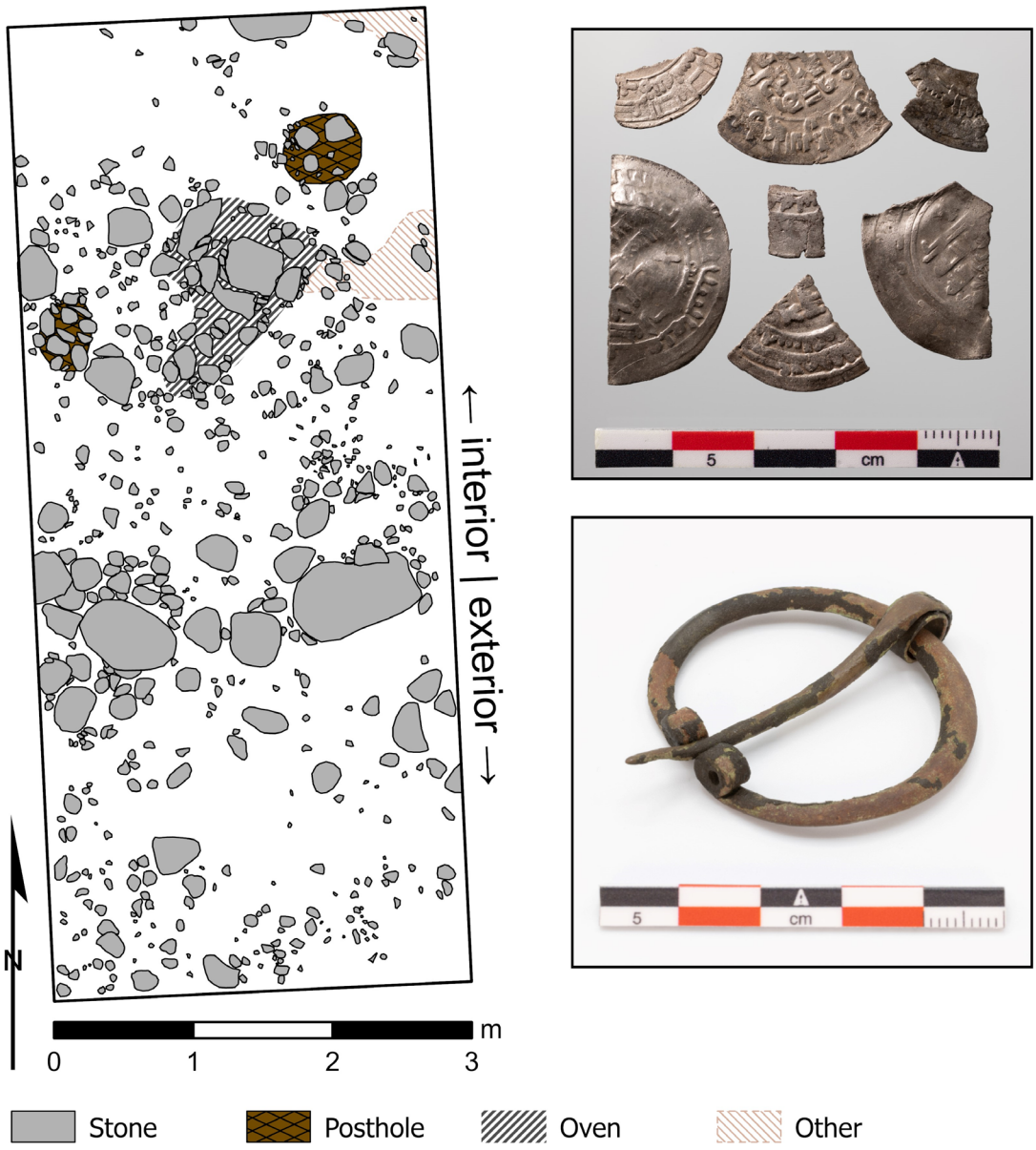

Figure 5. House 3 with its postholes, oven feature, and an indication of the interior and exterior areas separated by the stone wall; stones represent mechanical layer 2. Insets: Fragments of different Samanid dirhems from the first half of the 10th century and a copper-alloy horseshoe-shaped brooch with spirally rolled-up terminals, dated from the Viking Age until the 13th century. Map: K. Ilves and W. Perttola, photos: W. Perttola.

early 11th century (see also Ilves 2025). Even this building shows signs of several usage phases with the large oven structure being part of it in its youngest phase. The function of the house may have changed over time, but during its last usage phase, it likely served for crafts and trade.

Due to a large number of diagnostic artefacts discovered, House 3 was radiocarbon dated with seven radiocarbon samples (Table 1): all samples but one come from inside the house. While five of the samples from inside the house were dated to calAD 680–973 (Ua-77101, 77102, 77103,

77104, 77104), two samples were dated to the Roman Iron Age, to calAD 249–413 (Ua-77100, 77106).

House 4

House 4 (Ilves et al. 2025) closely resembles House 1 in terms of construction (Fig. 6) and its likely usage. These two houses are approximately 50 metres apart (see also Fig. 1). The three-aisled House 4 is today the most visible of the house structures at Bartsgårda due to the shallow ditch surrounding the building; it is located about 40 metres east from the edge of the cemetery. During the investigation, an 18 m long and in total 20 m²-sized trench was placed across the building so that areas outside both long sides of the house could be examined. Interestingly, the outside area facing the burial field was almost entirely devoid of finds from the Late Iron Age but provided lithic flakes and objects as well as pottery of older characteristics. Similar to the house investigated by Cederhvarf at the beginning of the last century (see above), this Iron Age house, as evidenced by artefacts, clearly lies atop a much older settlement. Excavation further established that a post-built dwelling had existed on the site prior to the construction of the stone foundation.

Inside the house, a large quantity of finds related to residential activity was discovered. The excavations yielded 3.7 kg of osteological remains and 2 kg of ceramics. Among the notable artefacts are two small and well-preserved objects from the Viking Age: a decorated one-piece single sided comb and a dot-in-circle decorated ringed pin (Fig. 6 inset, see also Ilves 2025). There are also other remarkable objects, such as a pendant made from a bear claw, which is a rare find from an Ålandic settlement context. The osteological analysis (Storå & Frid 2024) continued to add to the species variety of the Late Iron Age subsistence strategies at Bartsgårda, most notably through the identification of a domestic hen. The overall osteological material points towards prosperity, flexibility, and ecological security of the inhabitants. However, burned bone

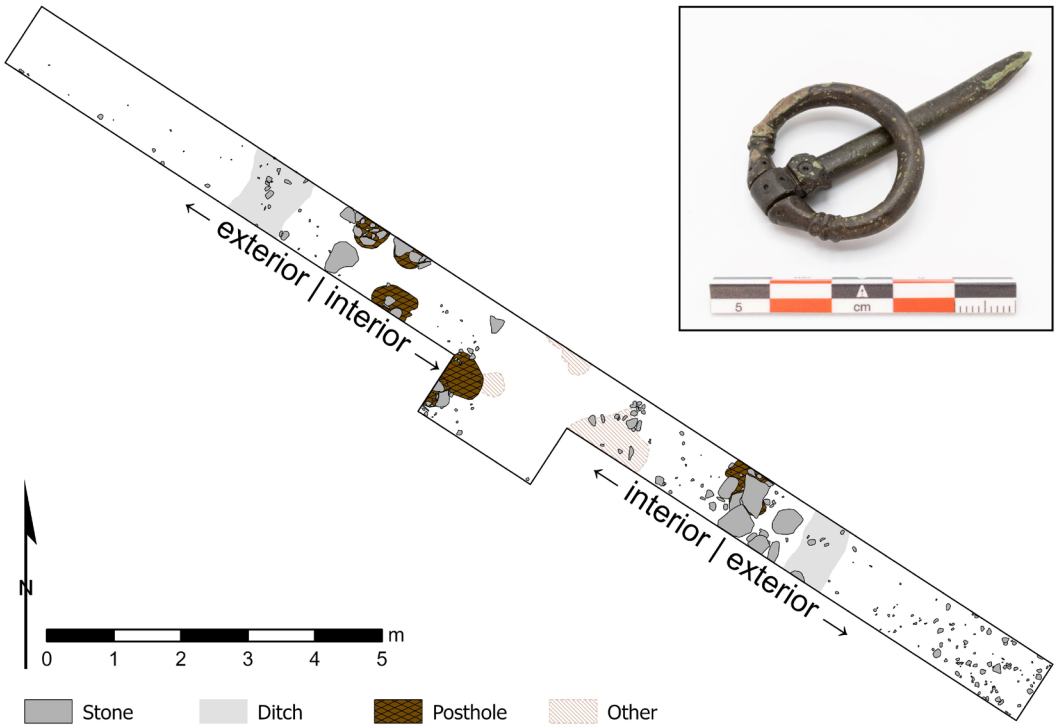

Figure 6. House 4 with its postholes and an indication of the interior and exterior areas separated by the stone wall; stones represent mechanical layer 3. Inset: A very short copper-alloy ringed pin decorated with dot-in-circle ornamentation, dated to the Viking Age. Map: K. Ilves and W. Perttola, photo: W. Perttola.

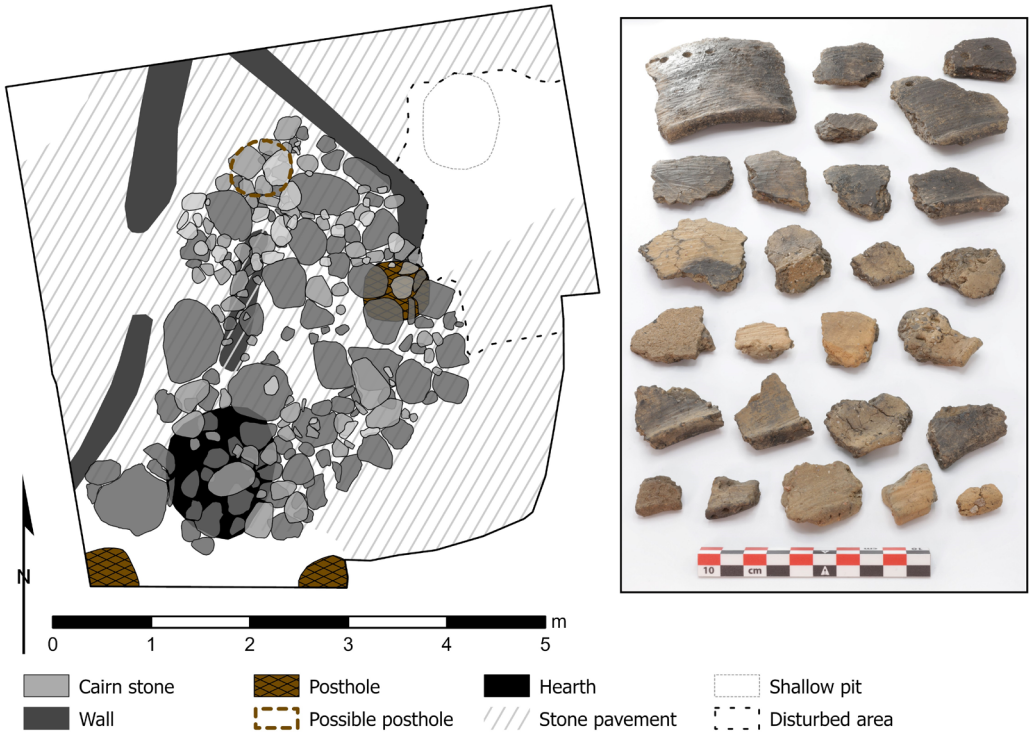

Figure 7. Interpretation map of the stone setting and related features. Inset: Selection of household pottery typologically dated to the Bronze Age and Early Iron Age. Map: K. Ilves and W. Perttola, photo: W. Perttola.

fragments from a dog indicate a tragic end to the dwelling.

House 4 was radiocarbon dated with 11 samples (Table 1), 10 of which, both from inside and outside the house were dated similarly to the other excavated houses at the site to cover the period from the second half of the Merovingian time to the end of the Viking Age, to calAD 672–993 (Ua-80909, 80911, 80912, 80913, 80914, 80915, 80916, 80917, 80918, 80919). However, one sample taken from the area outside the house, toward the cemetery – which lacked defined features but did include finds – was dated to the end of the Bronze Age, to 829–773 calBC (Ua-80910).

Stone settings

When the first dating results to the end of the Bronze Age and to the Roman Iron Age were obtained during the investigations of House 2 in 2021, the entire archaeological area was 'reassessed' and surveyed. As a result, among other things, small round and flat stone cairns were observed in the southern part of the area (see also Fig. 1), more than 100 m from the nearest stone foundation houses, close to and at the edge of a modern ditch that delineates the archaeological area from the surrounding farmland. This observation led to the hypothesis that these could be the burial cairns from the Early Iron Age, which on Åland are of such form and size, and often can occur together and be confused with more recent clearance cairns. Two of the newly discovered stone settings were excavated during the years 2022–23.

The first examined feature was a clearance cairn, from the bottom of which the radiocarbon-dated sample was collected, yielding a date of calAD 1440–1621 (Ua-76440). The second stone setting, however, turned out to be neither a clearance cairn nor a burial. This feature consisted of a low cairn covering a stone pavement layer that

extended beyond the cairn's edges, alongside the remains after several wall structures, postholes and a hearth or an oven (Fig. 7). Within a 28 m²-sized investigation area, the find material mainly consisted of large amounts of pottery and burnt clay: 4.2 kg and 7.4 kg, respectively. The latter was discovered mostly in connection with the hearth/oven feature – many fragments bear impressions from twigs and branches. The ceramics belong typologically to a time span covering the entire Bronze Age and a large part of the Early Iron Age (Fig. 7 inset; Ronkainen 2024). Despite the limited size of the excavation area, it is possible to speculate that the investigations concerned settlement remains, probably a house, which during or shortly after the abandonment was superimposed by a stone cairn. The same area was, however, also used centuries later, during the Late Iron Age, as attested by diagnostic artefact finds and radiocarbon dating results.

Radiocarbon analysis (Table 1) of six samples dated the cairn and the underlying stone pavement as well as two of the wall structures and hearth remains to the period 778–390 calBC (Ua-76441, 76442, 81525, 81526, 81531, 81533), i.e., to the end of the Late Bronze Age and beginning of the Early Iron Age. Among the dated material, there is a flax seed from the end of the Bronze Age (778–520 calBC, Ua-76442), which is the oldest dated flax from Finland (Vanhanen & Ilves 2025). One of the postholes was dated to calAD 894–1024 (Ua-81532) and there is another Late Iron Age dating result (Ua-81530) from the area outside of the cairn as well. Furthermore, a fragment of a gilded equal-armed brooch and a narrow-bladed war arrowhead uncovered during the excavation of this stone setting also belong to the Viking Age. This points towards the fact that even the area more distant to the surviving stone foundation houses has been part of the active landscape usage during the Late Iron Age. Three samples of charred horsetails from the upper layers of different contexts in the investigated area were dated to the period calAD 1040–1213 (Ua-81527, 81528, 81529) and interpreted to mark an early medieval fire event.

MODELLING OF ^{14}C-DATES

The investigations conducted at Bartsgårda revealed a settlement with complex spatial organization, prolonged periods of use, and distinct functional differences among its structures. The site has a total of 55 radiocarbon dates, collected from eight different context groups (but including sub contexts), which were dated ranging from the Late Bronze Age to the medieval period. The main bulk of the dates were derived from four stone foundation houses that were also the focus of the investigations at Bartsgårda. The results verified the active use of all the investigated stone foundation houses during the Late Iron Age. The range of the radiocarbon dates seem to suggest that the houses have been more or less in simultaneous use from the mid-7th century to the end of the 10th century. However, we decided to employ Bayesian modelling in order to determine whether it would be possible to nuance this picture and to investigate to what extent these structures actually were contemporaneous or if there are sequential phases of activity, reflecting changes in social organization over time.

The Bayesian approach to radiocarbon dating aims to refine the prior probability densities associated with each date by incorporating archaeologically derived assumptions, resulting in a posterior distribution that is typically more precise (Buck et al. 1992; Bayliss 2009; 2015; Bronk Ramsey 2009; Buck & Juárez 2024). The Late Iron Age radiocarbon dates from each house at Bartsgårda were modelled separately using OxCal 4.4 (Bronk Ramsey 2009; 2017) and the IntCal20 (Reimer et al. 2020), in order to explore the most plausible use phase for each house and assess the extent to which they may have been in simultaneous use. The entire cultural deposit in each house was treated as a single "occupation" phase, without consideration of the relative sample position in the stratigraphy. The prior assumption is simply that the dated events from each house all belong to this occupation phase and can be expected to relate to each other. In the model two boundary events are created – a start event and an end event – that are not themselves directly dated but serve as brackets constraining the dates entered into the model, which are assumed to fall within the range of the boundary events (Bronk Ramsey 2009:

343–345). Initially, a uniform phase model was employed, in which the events are equally likely to occur at any point between the boundaries (Bronk Ramsey 2009: 345). This resulted in poor individual agreement indices in several cases and the model was therefore modified to a normal distribution at the start boundary (Sigma_boundary), which represents an initially low but gradually increasing likelihood of events occurring at the beginning of the occupation phase (Bronk Ramsey 2009: 346). This model yielded both individual and overall agreement indices for the models above 60%, indicating a good agreement between prior and posterior distributions (Bayliss 2007). One late date (Ua-80919) in House 4 was flagged as an outlier due to poor agreement and subsequently excluded from the model. Summarized distributions were calculated on the posterior distributions (Bronk Ramsey 2017) and included in Fig. 8 together with the proposed date ranges for the boundary events and overall agreement indices for each house.

Treating the dates from the house features at Bartsgårda in this way seems to let us highlight the most probable phase of intensive use of each structure. Based on unmodeled dates, all the houses appear to originate in the 7th century and be in use well into the 10th century, and beyond. However, the Bayesian analysis changes this picture (see also Fig. 8), after which the only house whose start boundary stretches back to the 7th century is House 2. The next house to be founded seems to be House 3, at the earliest just at the beginning of the 8th century, whereas the most notable change occurs for Houses 1 and 4, which, according to the model, were founded at least a century later, during the second half

House	Agreement	Unmodeled range	Boundary start	Boundary end
House 1	93,7	AD 645 - 1021	AD 752 - 896	AD 917 - 1032
House 2	75,6	AD 645 - 989	AD 623 - 780	AD 771 - 935
House 3	119	AD 680 - 973	AD 703 - 880	AD 786 - 952
House 4	119,7	AD 672 - 993	AD 763 - 874	AD 793 - 901

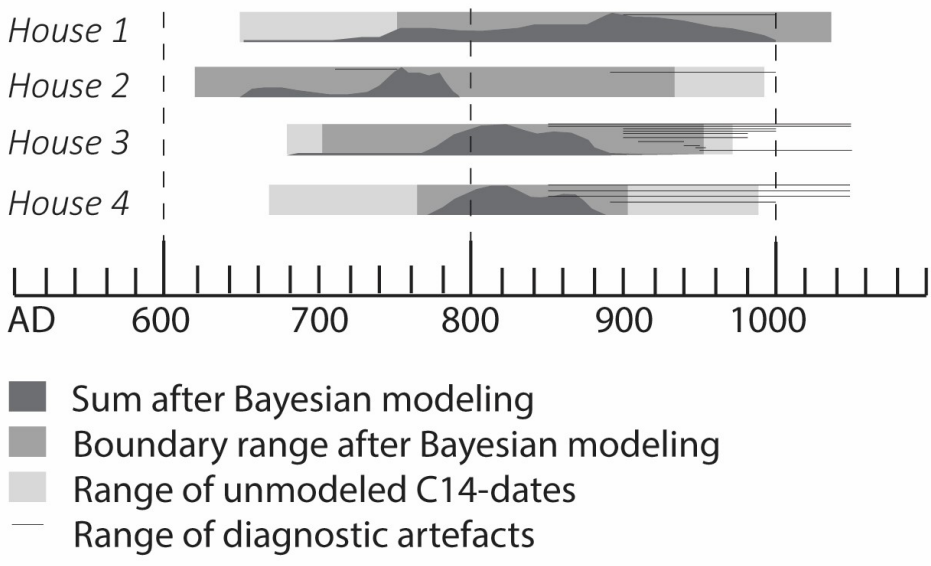

Figure 8. The chronology of Late Iron Age use of the house foundations, comparing unmodeled and modeled ^{14}C-dates and diagnostic artefacts. Figure: K. Darmark.

of the 8th century. All four houses were in simultaneous use during the latter part of the 8th century, throughout the 9th century, and into the early 10th century. The radiocarbon dates would suggest that Houses 2, 3, and 4 were not intensively used after the first half of the 10th century, at the latest, while there is a prolonged use of House 1 after the other houses were discontinued according to the modelling results. However, this early 10th century abandonment is countered by artifactual evidence, particularly from House 3, dating to the late Viking period, as also discussed below.

DISCUSSION

Early settlement phases

Based on the investigations, the first settlement at Bartsgårda is dated to the Late Bronze Age and Early Iron Age, roughly between 800–400 BC (see also Table 1). This settlement covers a large area. Lithic and pottery finds, along with a few radiocarbon dates, provide evidence of Late Bronze Age habitation layers beneath some of the Late Iron Age buildings as well as in the cemetery area. Dwelling structures from this period were documented at a distance of more than 100 m from the area with stone foundation houses. These features, superimposed by a stone cairn discovered at the southern edge of the Bartsgårda settlement site, are of considerable importance. This is partly because there is very little research on Late Bronze Age settlements on Åland. Aside from the comprehensively studied seasonal seal-hunting site of Otterböte, located on the island of Kökar (Kö 6.16, Gustavsson 1997), only a few other sites – such as Tjärnan (Sa 20.11, Meinander 1953), Godby (Fi 8.11, Under Godbyvägen 1984) and Hummelkärr (Lu 3.3, Andersson 1990) – have been published (see also Strömberg & Anderberg 2010). Additionally, little is known about Ålandic building structures from this period (for southwestern mainland Finland, see Asplund 2002). In addition to the ring-shaped tent-like hut foundations of stone found at Otterböte and Tjärnan, hut remains have been documented at Kulla (Su 13.10, Törnblom 1980) and Hummelmyrshägnaden (Su 21.2, Dreijer 1938), though these have not been discussed to any meaningful extent.

Although the limited excavation area must be taken into the consideration, it seems that the building remains documented at Bartsgårda differ from these huts. The complex at Bartsgårda is defined by stone pavements and wall ditches (see also Fig. 7); a circular hearth and a couple of postholes are also part of the traces. One of the geographically closest parallel to such a structure is the very first house dated to the Bronze Age in Sweden, from Boda in Uppland, studied by Oscar Almgren (1912). This building consisted of a circular structure with a stone-paved floor, postholes, a hearth, and abundant amounts of wattle-and-daub, as well as pottery of a Late Bronze Age type. Notably, later research has shown that this type of building does not represent the norm for Late Bronze Age building style, and Helena Victor (2002: 123–128) suggests that this type of structure may have served as a small cult house.

A similar interpretation could be valid for the Late Bronze Age building at Bartsgårda as well, especially as a cairn was constructed over the earlier structures shortly after the house was abandoned (see also Victor 2002: 36–39). While the cairn in this case does not appear to have been a burial feature, its construction recalls more widely known practices from especially the Iron Age in Scandinavia, where cairns or burial mounds – sometimes without human remains – were deliberately placed over earlier domestic structures (e.g. Thäte 2007; Allberg 2012; Eriksen 2016; Dahl 2023). Furthermore, five fragments of pottery connected to the stone pavement layer under the cairn were subjected to lipid analysis and provided unexpected results. The results show that two of the samples contained porcine fat, two exhibited characteristics of either ruminant dairy or adipose fats, and one sample contained ruminant adipose fats, while the isotopic values connected to marine foods were low (see closer Ilves et al. 2024: 64–65 and Appendix 3). Considering the maritime setting of Åland, the domination of maritime resources, and the importance of particularly seals within the subsistence strategies of the period (e.g. Gustavsson 1997: 44–47; see also Holmblad 2010: 90–96), these results might fall within the context of rare

foods to be consumed on special occasions only (see however Pääkkönen 2023: 52–53, 66–67) and further indicate the ceremonial or ritual character of the Late Bronze Age building at Bartsgårda.

The next phase of occupation at Bartsgårda, as indicated by radiocarbon dates, falls between c. AD 250–400, corresponding to the Roman Iron Age. This phase is supported only by three dates from the cultural layers in Houses 2 and 3, without any unequivocal finds or structural remains. However, a chemical and elemental analysis of archaeological pottery from House 3, conducted using a handheld portable energy-dispersive X-ray fluorescence spectrometer (Ronkainen 2024), identified a distinct group of sherds compositionally different from most of the analysed pottery from the house. While most of the pottery clusters into a single group (including several sub-groups), this unique group also differs from the elemental composition of the pottery recovered from the Late Bronze Age and the Early Iron Age dwelling remains that constitutes its own group. All analysed pottery from Bartsgårda is however made of local clay. The sherds in this distinct group were primarily found from outside of the stone foundation house, in an area otherwise poor in finds, whereas the sherds belonging to the main group were recovered from inside the building, which was rich in Late Iron Age finds. Typologically, the House 3 pottery belongs to the general Iron Age (500 BC–AD 1050) coarse domestic ware, which has proven notoriously difficult to interpret due to its visual and morphological uniformity and the lack of clear stylistic or technological markers for differentiating chronological phases within this approximately 2000-years-long period (Lehtosalo-Hilander 1984: 344; Eriksson 2005: 201). While it cannot be stated with certainty that the pottery with a unique elemental composition from House 3, spatially associated with a distinct context, belongs to the Roman Iron Age, this remains a hypothesis worthy of more specific formulation and testing in the future studies (e.g. Eriksson & Lindahl 2012; see also Eslami et al. 2020).

Whereas the settlement dating to between c. 800–400 BC shows signs of being substantial, covering a large area, and including dwelling structures, the nature of the settlement at Bartsgårda during this period, but also during the Roman Iron Age, as well as their continuity with preceding and subsequent phases, is thus yet unknown.

Late Iron Age establishment, use and abandonment

The Late Iron Age is the most archaeologically conspicuous settlement phase at Bartsgårda, with the cemetery of over 100 individual mounds interpreted as burials, and several tens of stone foundation houses, five of which have been excavated and presented in this article. Judging from the Bayesian analysis conducted on the ^{14}C-dates from the buildings studied in the 2020s, it can be concluded that the houses are not all established at the same time. House 2, with its argued special, possibly ritual character, is the first house to be established in the early 7th century. This house has a remarkably long lifespan, at least 300 years, before being abandoned in what seems to be an orderly fashion, again with possible ritualistic overtones. According to the model, the next house to be established, House 3, appears to have been founded no earlier than the beginning of the 8th century, and Houses 1 and 4 were established during the second half of the 8th century. All four houses were in use concurrently from the late 8th century through the 9th century and into the early 10th century, a prolonged occupation that is also reflected in the traces of rebuilding and reconstruction documented in all houses. At least two of the buildings, Houses 1 and 4, were first established as timber structures and have received their Åland characteristic stone frames at a later stage; both buildings also have evidence of post replacement, indicating repair. Traces of post replacement were documented in House 2, too. In case of House 3, a rectangular oven structure as well as a couple of postholes have been built over earlier occupation layers, indicating changing spatial layout and function over the time of its use.

It is of interest to see this high degree of curation and long life span of the Bartsgårda houses. Although there is quite a large flat area to the south of the identified house foundations (see Fig. 1), the settlement seems to have not

been allowed to expand in this direction, which simultaneously raises the question of Late Iron Age private property and the question of what the southern field was used for during the period.

The area with house foundations covers at least 1.3 hectares, and the excavation results point to a Late Iron Age settlement that developed over several centuries. The chronological variation in house establishment inevitably raises questions about the underlying reasons for constructing new houses at different times. Were these shifts driven by demographic changes, economic strategies, or broader societal transformations? It is noteworthy that the period of AD 750–950 crystallizes as the phase of intensified occupation at Bartsgårda, which coincides with the chronology of the Viking Age – a time marked by increased mobility and expansive trade networks in the North. During this period, the Åland Islands witnessed its greatest economic affluence as a result of Scandinavian eastern expansion (see also Ahola et al. 2014). The establishment of more houses at Bartsgårda during this time, along with artefactual finds related to trade and external contacts, reflects participation in these broader economic and cultural dynamics. The period brings silver, and both directly imported luxury items as well as know-how to establish endemic and unique jewellery production (see also Ilves 2025); subsistence strategies point towards a varied economy that demonstrates wealth and access to a diverse set of food items, including ones considered of high value, such as bread wheat (see closer Leppäsalko & Vanhanen 2023; Vanhanen & Ilves 2025).

The construction of new dwellings likely accommodated an expanding population. Furthermore, the spatial organisation of the settlement, characterized by its concentrated layout and evident continuity of use, indicates a deliberate effort to maintain control over this specific area. This strategic choice could be linked to Bartsgårda's significance within a regional network of communication and exchange. Although Bartsgårda clearly is an affluent settlement, it is not an easy task to determine its socioeconomic position in relation to other Ålandic multi-building sites exhibiting wealth, such as Kvarnbo, Kohagen, or Gölby (cf. Ilves 2018; 2019b; Ilves & Darmark 2020), since the Viking Age appears to bring a general economic boost to the region. Based on current evidence, however, all these sites seem to display significantly more wealth than the single farms that have been excavated, such as Kulla – also in use between c. AD 650–1020 (Ilves 2018: 77–78) – suggesting radically different developmental trajectories and possible social stratification between different categories of settlements.

Even though the investigations conducted at Bartsgårda affect only a small selection of all presumed houses, and only a fraction of each house, there are clear signals of differences in house function. House 2 constitutes a most interesting deviation from the rest, both by possibly being divided into longitudinal rooms that is uncommon (also Rosberg 2024: 51), and by the conspicuous sparsity of finds, while the relative lack of osteological and palaeobotanical material strongly hints at an unusual structure. The house, which also has weakened anthropogenic signals in the geochemical data, has been interpreted to be connected to ritual activities and meanings (Holmqvist & Ilves 2022a: 381, 393–394). It must be stressed, that buildings for private cult practices at the time most probably are architecturally similar to profane buildings (Einarsson 2008), and the suprapositioned layer of fire-cracked rock as documented in case of House 2 could in such a scenario either indicate a ritualized abandonment "burying the house" or a continued use of the house after abandonment. Such practices are both attested in connection to Late Iron Age cult-related structures (e.g., Nielsen 1996: 98; Bäck et al. 2008: 35–36; Ljungkvist & Frölund 2015: 18). House 3, which might have been founded as a dwelling, shows signs of being converted to a more specialized function at the later stages, which is reflected through the construction of an oven and the find assemblage, unusually rich in objects connected to craft and trade. Neither House 1 nor House 4 display signs of being anything other than residential buildings, although these do exhibit some internal differences, for example in regard to food production and processing (Leppäsalko 2025).

It is notable that refuse has to a large degree been allowed to accumulate within the houses. Although cleaning must have taken place, there are no tangible refuse heaps in immediate connection to any of the houses. In several

instances, there are instead clear signs of floor renewal through the addition of sand to the floors. Even though the interior surface of the houses witnesses this continuous buildup of debris, there is a strong bias of diagnostic artefacts belonging to the later part of the period, between c. AD 850–1050. This is particularly true in Houses 3 and 4 where a number of diagnostic finds, such as the silver coins and beads presented above, which all have dating ranges stretching to about AD 1050 (see also Fig. 8), indicate a use phase beyond that which is obvious from the ^{14}C-dates, especially when modelled. This overrepresentation of diagnostic finds belonging to the end of the sequence, combined with a dearth of finds diagnostic of the earlier period, could possibly indicate a traumatic, unplanned abandonment of the settlement. The fact that most houses seem to have been burned down, together with the burned dog remains in House 4, and two war arrowheads (Fig. 9), one of which from House 3 and another found in a peripheral position at the southern edge of the settlement site, could indicate the violent nature of the end of the Bartsgårda settlement. An arrowhead was found from the house investigated by Cederhvarf as well. The datings from the houses themselves are not easily used to argue for when this would have occurred. The uppermost, youngest layers would probably be more subject to taphonomic loss than the layers sealed underneath, making it harder to find suitable, short lived datable material from the last phases of the structures. The Late Iron Age / Early Medieval fire event identified in connection with the stone setting in combination with the data from the houses could, however, place the abandonment of the settlement to the very end of the Late Iron Age period.

The fact that all the houses, save House 2, have yielded several artefacts that can be viewed as de facto refuse, in the sense that they are still usable, notably the objects made from precious metals, besides pointing towards the unplanned character of site abandonment, also indicate a longer break in settlement continuity. If Bartsgårda

Figure 9. Two Viking Age narrow-bladed war arrowheads from the site: the upper one discovered in House 3 and the lower one found in an upright position in the top layers of the investigation area related to the stone setting. Photo: W. Perttola.

would have had continuous settlement after the abandonment of the stone foundation houses, one would expect considerable scavenging of the visible and accessible ruins, where especially coins and jewellery, being both valuable and easily transported would be primary targets. There is evidence of an early medieval presence at the site, such as a few radiocarbon dates and the brooch found by Cederhvarf. In this context it is also relevant to point out that adjacent to the current site, just a couple of hundred meters to the southwest, there is a Late Iron Age cemetery registered as Fi 2.2 (see Fig. 1), investigated in the 1920s by Alfred Hackman (1924; 1925; 1926). At the western edge of that burial ground, several oval and rectangular stone settings were excavated, largely empty of finds, but with dark soil. These features bear certain similarity with the rectangular stone settings empty of finds at the edge of the fully excavated Late Iron Age cemetery at Kvarnbacken (Sa 2.4, Kivikoski 1963) that are argued to represent early Christian inhumation burials. It is thus possible to speculate the reestablishment of settlement at Bartsgårda, however, this settlement would have been established at least several decades after the fall of the Viking Age village, with somewhat shifted location, and it seems to have been of a much more modest character.

CONCLUSION

In this study, we have introduced the results of the investigations at Bartsgårda on the Åland Islands and presented a comprehensive chronological framework for the site, based on a series of 55 radiocarbon dates. Our findings reveal a complex occupation history spanning from the Late Bronze Age to the medieval period. By employing Bayesian statistical modelling, we have demonstrated a sequential establishment of the Late Iron Age houses, indicating that the settlement resulted from gradual growth from an assessed origin in the early 7th century, with new houses being added over time. Importantly, this does not reflect a pattern of residential mobility, where a new house is constructed for each generation. Several of the dwelling houses are constructed at the same time and the data particularly highlights a phase of intensified settlement activity between AD 750–950, which corresponds to the Viking Age's economic and cultural expansion in the region. During this period, Bartsgårda appears in all respects as a village rather than a farmstead, likely including functionally separate structures for craft and trade, and cultic purposes. It is argued that this substantial settlement, constituting an important early population centre for Late Iron Age Åland, experienced an unplanned abandonment at the end of the period, possibly due to external violence. Following this abandonment, a hiatus occurred before a new and considerably more modest medieval presence established itself. As a final remark, it should be reminded that the current research material still covers only a small portion of the site at Bartsgårda, and the conclusions presented here remain broad generalizations in light of the site's larger scale and research potential.

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Endnotes

[1] There are 13 Late Iron Age cemeteries on Åland, out of approximately 450, that have more than 100 grave mounds registered: Fi 2.1 and Fi 24.1 in Finström, Ha 21.1 and Ha 22.22 in Hammaraland, Jo 10.1 and Jo 22.4 in Jomala, Sa 14.1, Sa 2.4, Sa 23.5, Sa 28.6 and Sa 29.2 in Saltvik, and Su 12.12 and Su 12.7 in Sund.

[2] Radiocarbon dates are calibrated with software program IOSACal: v0.4.1 using the IntCal20 atmospheric curve (Reimer et al. 2020).

[3] This information about the number of excavated graves is extracted from the find catalogues. However, an examination of the finds related to Cederhvarf's investigations, stored at the Museum of Åland, provide evidence that at least two of the studied features (registered as mounds no. 105 and 106) near the sand pit are not graves but rather remains related to settlement activity. The finds, consisting of a large number of iron object fragments, substantial amounts of slag, including slag droplets, as well as burned clay, including slagged clay, indicate activities related to metalworking.

[4] The coins were identified by Jani Oravisjärvi (see Ilves et al. 2024: Tabell 6).

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Janne Soisalo

THE CHRONOLOGY OF THE PYHEENSILTA GROUP AND KIUKAINEN CULTURE IN FINLAND BASED ON RADIOCARBON DATING

Abstract

This study presents an analysis of radiocarbon (^{14}C) samples to date the Middle Neolithic Pyheensilta group and the subsequent Late Neolithic Kiukainen culture on the coastlines of present-day Finland. The Pyheensilta group is dated to approximately 3200–2650 BCE, while the Kiukainen culture is dated to around 2500–1750 BCE. The chronological data indicate that these Neolithic cultures were not contemporaneous; instead, the Kiukainen culture emerged after the Pyheensilta group had disappeared. Notably, the two groups are dated 150 years apart, suggesting a period of cultural change. This study provides insight into the temporal dynamics and cultural succession in Neolithic Finland.

Keywords: Stone Age, Pyheensilta group, Kiukainen culture, Radiocarbon dating, Finland

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INTRODUCTION

This article examines how the Middle Neolithic Pyheensilta group and Late Neolithic Kiukainen culture are dated, whether these groups partly overlap in time, and when the Pyheensilta group gives way to the Kiukainen culture. The terms discussed in the article, such as culture, group, and the definitions of various types of ceramics, are based on the history of Stone Age research and tradition in Finland. The study is based on both new and old radiocarbon dates of the Middle Neolithic Pyheensilta group and the Late Neolithic Kiukainen culture. Both cultural groups existed along the west and south coasts of present-day Finland. The Pyheensilta group has previously lacked all ^{14}C datings and the Kiukainen culture has previously been dated based on 11 radiocarbon datings (Pesonen 2021). All previously published ^{14}C dates from the Kiukainen culture have been collected from various sources and are included in here with the new datings. The article establishes chronological frameworks for both Stone Age cultures through radiocarbon dating based on the current state of research.

The new datings of the Kiukainen culture and the Pyheensilta group are highly significant for understanding the Middle and Late Neolithic Stone Age on the coast of present-day Finland. This period was a time of transition, during which the pan-European Corded Ware culture (CWC) spread in southern Finland from the Baltic region, starting from around 2850 BCE and continuing until around 2200 BCE (all BCE dates are calibrated; see Pesonen et al. 2019). This spread was part of larger population invasions and movements in eastern and central Europe from the Pontic-Caspian steppe (Sjögren et al. 2016; Kristiansen et al. 2017). Southwestern Finland was already inhabited by the local Pyheensilta group and in some parts

also by the Middle Neolithic Pöljä group (c. 3300–2500 BCE; see Nordqvist & Mökkönen 2021). This inevitably impacted on the lives of existing inhabitants, and the arrival of the new population led to major cultural, linguistic, economic, religious and ideological changes. Likely it also caused conflicts between these different populations. Encounters between the expansive CWC and the indigenous population resulted in various developmental trajectories across Europe (Edgren 1997; von Hackwitz 2009; Larsson 2009; Beckerman 2015).

The Kiukainen culture, which emerged along the coast and has features from both the Pyheensilta group and the CWC, comes to an end with the onset of the Scandinavian-influenced Bronze Age (Äyräpää 1922; Meinander 1954a; 1954b; Salo 2004: 114–115; Halinen 2015: 114; Lavento 2015: 125–126). The formation process and origins of the Kiukainen culture have so far been poorly understood, and its precise dating has remained unresolved. Similarly, there has been uncertainty regarding the dating of the end of the Kiukainen culture and the Stone Age. Traditionally, the transition to the Bronze Age has been considered a gradual process spanning many generations (Meinander 1954a: 183–186; Salo 1981: 39; 2004: 140–141; Huurre 1991: 307).

RESEARCH HISTORY OF THE PYHEENSILTA GROUP

The Pyheensilta group inhabited the southern and western coastlines of present-day Finland (Meinander 1939; 1954a; Edgren 1956; Vikkula 1987; Pesonen 2021; see Fig 1). It could just as well be considered its own culture, as the communities within it had their own way of living. The group also had its own distinctive style of pottery, which set it apart from other contemporary groups (Meinander 1939; 1954a; Edgren 1956; Vikkula 1987; Pesonen 2021). Pottery resembling that of the Pyheensilta group has been also found in Kainuu, present-day north-east Finland and Lake Ladoga, now in Russian Karelia (Vikkula 1987), but these areas have been left out of this study because of the geographical distance and other uncertainties such as small number of potteries, multiperiod settlement sites and unconfirmed identification. The distribution of Pyheensilta Ware presented in the study is based on my observations and previous research (Vikkula 1987; Pesonen 2021).

The Pyheensilta group was first dated by Carl Fredrik Meinander based on postglacial land uplift to the end of the Late Comb Ware period or younger (Meinander 1939). Later, Meinander considered the Pyheensilta group to be contemporaneous with the CWC and preceding the Kiukainen culture (Meinander 1954a). Subsequently, the relative dating of the Pyheensilta group compared to other Neolithic groups has not changed significantly, but its absolute dating in calendar years has varied. Anne Vikkula dated it to 2600–1750 BCE (Vikkula 1987: 158), also based on postglacial land uplift. After this, the group was dated earlier with the widespread use of radiocarbon year calibration. Carpelan (1999: 260–264) dated it to 3200–2800 BCE, suggesting that the communities belonging to the Pyheensilta group quickly adopted the lifestyle and material culture of the CWC and then merged into these societies. The latest proposals are to date Pyheensilta group to around 3200–2400 BCE (Halinen 2015) or 3400–2700 BCE (Pesonen 2021: 93).

Pyheensilta Ware is defined based on the findings from the eponymous settlement site Pyheensilta in Mynämäki, Southwest Finland (Meinander 1939; Vikkula 1987). The vessels have a round pointed base, with usually straight walls, although profiled walls or inward-bent rims also occur. The clay material is typically mixed with organic temper, but sand and crushed stone mixtures are also present. Using asbestos as temper has not been detected. The whole surface of the vessel is sparsely decorated. The most common decorations include long and narrow comb-stamped motifs or lines, but others include wide or oval comb-stamped motifs, fingernail impressions, ring impressions and triangular impressions. The most important decorative feature is the absolute absence of pits (Vikkula 1987: 59–62). Typically the vessels are poorly fired, resulting in poor preservation and fragmentation of the ceramics. Identifying Pyheensilta Ware is therefore often challenging. No comprehensive study has been published on the stone tools used by the Pyheensilta group.

Characteristic stone artefacts for the group are made of slate. They include long arrowheads, various small fishing weights and small chisels (Meinander 1939; 1954a: 158; Edgren 1956).

The Pyheensilta group has been studied only to a limited extent, and it is typically considered part of the prehistoric cultural continuum, temporally situated between the Late Comb Ware culture and the Kiukainen culture (Meinander 1954a; Halinen 2015). Current knowledge suggests that its subsistence was based on maritime hunting and fishing, with no evidence of agriculture or animal husbandry (Fortelius 1980; Vikkula 1987: 168; Nurminen 2022; 2023; 2024b; 2024c). The largest settlements were in Harjavalta at the ancient estuary of the Kokemäki River and in Mynämäki. Other settlements used by the Pyheensilta group are small and have relatively few finds connected to this group. Many settlements are multiperiodic, containing only small amounts of Pyheensilta Ware from a few vessels, even if the settlement itself is large (Vikkula1987: 150). In many cases we can only notice that the multiperiod settlement sites have been used or visited also by the Pyheensilta group.

RESEARCH HISTORY OF THE KIUKAINEN CULTURE

The Kiukainen culture was a coastal Neolithic culture that existed on the southern and western coasts of Finland, starting at the Late Neolithic and continuing until the Bronze Age. Its central distribution area extends from southern Ostrobothnia to the Gulf of Finland near the Helsinki region, but only a few inland settlements have been discovered (Meinander 1954a; Soisalo & Roiha 2022; see Fig. 2). Outside the core area, Kiukainen Ware has been found mainly in some multiperiod Neolithic settlement sites. The Kiukainen culture was a uniform cultural group in terms of pottery and stone artefacts, as well as in terms of living in a maritime environment, along the Baltic coast.

Kiukainen culture was first identified as a unique cultural form by the Finnish archaeologist Julius Ailio (1909: 71–84), and since then it has, periodically, been the subject of more focused research. The only in-depth study dealing with the culture is Meinander's 1954 book *Die Kiukaiskultur*. Previous research on the Kiukainen culture is therefore old and reflects its own time. During the last few decades

1. Mynämäki Pyheensilta.
2. Harjavalta Hiittenharju, Lyytikänharju & Palokangas I.
3. Eura Printunrinta.
4. Kemiönsaari Långsidsmossen.
5. Espoo Korkoontie.
6. Vantaa Maatalouden tutkimuskeskus.
7. Porvoo Vävarsbacka II.
8. Lieto Ristinpelto.

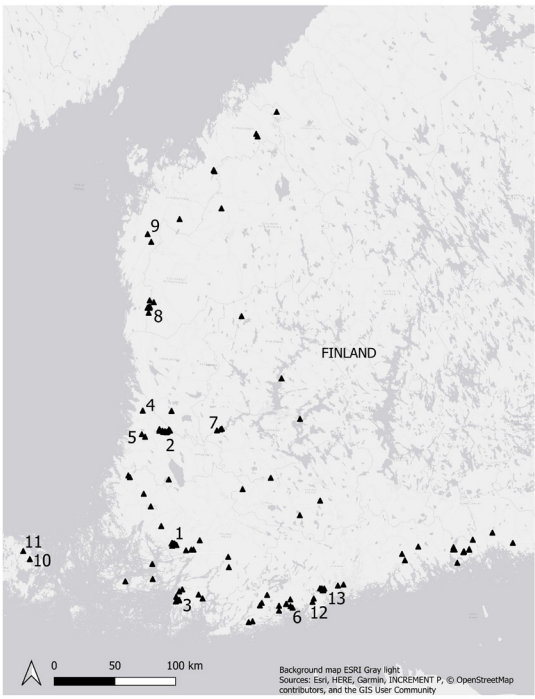
Figure 1. Distribution of Pyheensilta Ware and analysed sites. Map: Johanna Roiha.

new material has been collected from many excavations, making an update to the research situation needed.

Kiukainen subsistence has been seen as comprising a mixture of foraging and farming (Meinander 1954a; Huurre 1991: 233; Salo 2004: 121–136; Alenius 2008; Lempiäinen-Avci et al. 2024). Also, during this period, the first stone tools connected to agriculture are found. Stones suitable for grinding grain have been found in many settlement sites, but their dating to the Kiukainen culture is not completely certain (Ailio 1909: 82; Meinander 1954a: 113; Huurre 1991: 233 Salo 2004: 123–124). Moreover, so called narrow-edged axes, which may have been used as ploughs or hoes, have been connected to Kiukainen culture (Meinander 1954a: 98–101). The stone objects of the Kiukainen culture are unique, and typical for it are so-called Kiukainen-type axes, small chisels and fishing weights. Flint daggers and sickles were imported from Scandinavia, as well as shaft hole axes, which were also made locally (Meinander 1954a: 76–133). The precise dating of stone tools is difficult, as all flint daggers and sickles are stray finds, as are almost all shaft hole axes.

Meinander characterised the shape of Kiukainen Ware vessels as usually thick-rimmed and rough-made. They are always flat-based and often straight-edged, but mild profiling occurs sometimes. The vessels vary in size from small beakers to large storage vessels. Clay material was often mixed with crushed stone or sand, but organic temper was used, especially in southwest Finland, causing the ceramics to be porous. Usually, only the upper part of the vessels is decorated, but sometimes textile imprint can be found on the lower part. The decoration is usually horizontal and made of rows of pits, dots, lines, comb or ring stamps, impressions or imitations of twisted cord. Horizontal or vertical zig-zag lines are also typical. Though other decorations have been found, the vessel is usually decorated only with a row or rows of pits and perhaps one other decorative element.

The Kiukainen culture has traditionally been considered the final phase of the Neolithic Stone Age on the coast of Finland, ending with the Bronze Age. However, this cultural phase has been relatively poorly studied, and ideas about its duration and precise dating have varied over time. Initially, Aarne Äyräpää dated it after the CWC and Late Comb Ware periods, towards the end of



1. Turku Kotirinne and Riihivainio.
2. Harjavalta Kraakanmäki 1–3.
3. Kemiönsaari Ölmosviken, Hammarsboda 2, Knipäng & Jordbro.
4. Pori Kirkkokangas IV.
5. Eurajoki Etukämppä.
6. Inkoo Kasabergen.
7. Sastamala Hiukkasaari.
8. Kristiinankaupunki Lappfjärd-Kyttåkersbacken, Langäng, Lillsjö & Norrviken.
9. Närpiö Pörtom-Raineåsen.
10. Saltvik Myrsbacka.
11. Saltvik Härdalen.
12. Kirkkonummi Kolsarby.
13. Espoo Backisåker.

Figure 2. Distribution of the Kiukainen Ware and analysed sites. Map: Johanna Roiha..

the Stone Age (Äyräpää 1922: 165–169). In the 1920s, the general phasing of Finland's Stone Age chronology was still being established, and the Pyheensilta group was unknown. Later it was dated based on postglacial land uplift to 1650–1200 BCE, corresponding to Montelian Period II of the contemporary Scandinavian Bronze Age (Meinander 1954a: 183). Meinander also suggested that the use of Kiukainen Ware continued at least for some time into the Bronze Age. This suggestion has been widely accepted, and it has been concluded that it continued even into the middle of the Bronze Age until around 1000 BCE, during Montelian Period III (Carpelan 1979: 10–11). Later Kiukainen culture was dated to 2350–1700 BCE, which aligns closely with current views (Carpelan 1999: 273). However, in the 21st century, the dating of the Kiukainen culture has been slightly revised to 2500–1800 BCE (Halinen 2015: 58). The latest dating based on (^{14}C) samples related to the Kiukainen culture is 2500–1750 BCE (Pesonen 2021: 97).

RADIOCARBON DATING AND ITS CHALLENGES AND LIMITATIONS WITH STONE AGE MATERIALS

There are always numerous possible sources of error in radiocarbon dating. First, it is important to ensure that the sample truly represents the subject being dated. Later the sample can become contaminated with more recent carbon, for example through mould growth. Measurement errors in the laboratory and differences between laboratories can occur (Scott et al. 2007). Additionally, calibrating the results to calendar years and calibration curves can introduce a potential source of error.

When dating the charred food residue of Stone Age pottery, special attention must be paid to the possible Marine Reservoir Effect (MRE) resulting from carbon derived from the sea (Pesonen 2021). MRE can potentially offset the dating result by over three hundred years (CHRONO Marine database, http://calib.org/marine). Both the Pyheensilta and Kiukainen cultures were predominantly coastal, with maritime fishing and hunting playing a significant role in their subsistence. Therefore, it is expected that a significant MRE may be present in some of the pottery residue samples.

Except for Hiukkasaari in Sastamala and Vävarsbacka II in Porvoo, all the sites included in the study were located on the coast, and all corrections have been made taking MRE into account. At least in theory, they may still contain traces of carbon originating from freshwater because we really do not know the content of the vessels. Ceramic vessels were used for storing, for preparing food and as drinking cups. Many of them were also used for cooking over the fire at some point of their lifecycle as can be seen from soot and burn marks on their side. Research on the charred food residues in these vessels has confirmed the presence of marine-derived products in at least in some of them (Pääkkönen et al. 2019). Despite uncertainties, the charred food residues can be dated quite reliably as they specifically relate to vessel use. The dated carbon in the charred crust is derived from animals and young plants, which died recently before cooking. There is always a possibility that the dated sherd was in the fire after use but dating the crust instead of the soot reduces the likelihood of error. This allows for dating even at multiperiod sites, if the vessel fragment is sufficiently large to be identifiable.

The possible MRE in the charred food residue samples of the pottery has been estimated using the carbon stable isotope value (δ^{13}C), which is always reported here, when available. This value reflects the aquatic composition of the charred food crust, and the terrestrial/marine limit is set to –26 ± 1‰ (Fischer & Heinemeier 2003). The 100% marine content limit in the crust is a δ13C value of –19.3 ± 2.0‰ (Pesonen 2021). In the northern Baltic Sea area (between 59° and 66°N latitude), the current average value of the MRE is estimated as 231 ± 113 ^{14}C years (N=8, CHRONO Marine database, http://calib.org/marine). The marine composition is calculated arithmetically between 100% marine and 100% terrestrial values. However, the calculations may contain inaccuracies, and the obtained values cannot be interpreted literally. The method itself creates new potential sources of error, as inaccuracies may arise in the laboratory when determining the δ^{13}C value.

The following formula has been used here to calculate the MRE: δ^{13}C -1‰ = 34.48 ^{14}C

years with ± 16.9 years of possible error. Even modelled dating should be approached with caution, especially if the MRE is significantly large. This is based on observations from studies conducted in the Baltic Sea, which indicate that determining precise values for MRE is complex, with many variables (Lougheed et al. 2013).

Cremated bone is a good dating material since it can be reasonably assumed to date human activity at the site. When bone burns, the carbon it contains is released, along with any potential MRE (Hüls et al. 2010; Van Strydonck et al. 2010; Olsen et al. 2012). Therefore, burnt bones of marine animals, often abundant at settlement sites, are suitable for dating. Studies indicate that dating burnt bone reveals the age of the wood used in the fire (Hüls et al. 2010; Van Strydonck et al. 2010; Olsen et al. 2012). The burnt wood can be hundreds of years old if it is from the centre of the tree (old wood effect) and reuse of older wood structures as firewood is possible. Dead trees can stand for centuries in some conditions and still be used as firewood. The average old wood effect has been suggested at 42 ± 79 ^{14}C years for the charcoal (Oinonen et al. 2010) and age of 73 ± 26 ^{14}C years for the cremated bone (Olsen et al. 2012). The sources of error associated with old firewood can generally be considered valid for dating charcoal collected from cultural layers or hearths. However, caution must be exercised with charcoal, as it can occur in the soil due to forest fires and subsequent human activity.

The most precise dating in theory is obtained from dating charred nutshell and other macrofossils as they are annual fruits and so reflect the year of harvest. European hazelnut (Coryllus avellana) does not naturally grow on open sandy beaches, where most settlement sites in this study once were (Väre et al. 2021). The nuts were very likely picked and brought to the site by humans when they were used for nutrition.

To reduce the impact of errors in dating individual samples, Bayesian modelling was used. This was done with OxCal software (Bronk Ramsey 2021), which is the most used application for Bayesian modelling in archaeology. The data of the samples that were accepted have been reviewed, to confirm that they date back to human activities during the Stone Age. The Bayesian modelling practically makes the oldest datings younger and interprets accordingly the youngest samples as older within the framework of the calibration curves. The model compares the samples with each other and creates a model based on the probability of the samples in relation to one another, which also reduces the impact of a single dating.

The reliability of the Bayesian modelling depends on the accuracy of the samples. In this study, samples with an uncertainty of more than ±100 ^{14}C years, are considered inaccurate and thus excluded from the modelling. One excluded sample is placed at the very beginning of the Kiukainen culture, but no δ^{13}C value is available for calculating the MRE. A sample with an inaccuracy of ±99 ^{14}C years has also been removed from the end of the Kiukainen culture. All excluded samples are from the Kiukainen culture, because the number of samples is sufficient for modelling in any case. The excluded samples are presented in Appendix 2. One sample from the Pyheensilta group exceeds the threshold, but it was decided to keep it in the calculation because the number of samples is otherwise small, and the sample does not date to the beginning or end of the cultural phase. All calibrations in this article are done using OxCal v4.4.4. (Bronk Ramsey 2021), atmospheric data (IntCal 2020) by (Reimer et al. 2020).

MATERIAL

The Pyheensilta group datings (number 16) are all previously unpublished and have been collected on excavation projects I participated in and findings from my own surveys. Additionally, material has been gathered from the collections of the Finnish Heritage Agency, where archaeological discoveries from excavations in Finland are stored. These collections include Pyheensilta and Kiukainen Ware originating from previous archaeological excavations and surveys. Much of this material has been in the collections for decades.

The dated samples collected for this study on the Kiukainen culture also come from various sources. Some have been published in three dissertations (Asplund 2008; Pesonen 2021; Pääkkönen 2023) and others are available in excavation publications (Luoto 2004, Lehtonen

Figure 3. Examples of the dated Pyheensilta Ware. Clockwise from top left: KM 15324: 1 Lieto Ristinpelto, KM 42407 Espoo Korkoontie (dating from the find context), KM 10903: 232 Mynämäki Pyheensilta, KM 43783: 964 Porvoo Vävarsbacka II. Photos: Janne Soisalo and Marjo Karppanen.

Figure 4. Dated Kiukainen Ware. Left KM 44393: 450 Pori Kirkkokangas IV. Right KM 44121: 158 Kemiönsaari Ölmosviken. Photo: Marjo Karppanen.

Figure 5. Dated Kiukainen ware. Top, left to right: Kristiinankaupunki Langäng KM 12563: 23, Kristiinankaupunki Lillsjö KM 31881: 1. Middle, left to right: Närpiö Raineåsen KM 12221: 58 and KM 12545: 18. Bottom, left to right: Kemiönsaari Knipäng KM 11721: 6 and Kemiönsaari Jordbro 16544: 12. Photo: Janne Soisalo.

2005 and Pukkila 2019), or excavation reports (Haggrén 2011; Pesonen 2014a; 2014b; Laulumaa & Seppä 2021). Some previously published datings were only partially available and many researchers have kindly provided additional information upon request to ensure the comparability of results. Except for one, the previously unpublished datings are from excavation projects related to my research on the Kiukainen culture and from the collections of the Finnish Heritage Agency (J. Lucenius, FM, e-mail to the author 16 March 2023). Some of the Kiukainen Ware sherds dated now were found while I was examining the pottery in the collections to determine the distribution area of the culture. These sherds contained enough charred crust for dating purposes. This article compiles 54 datings related to the Kiukainen culture from various locations within its distribution area.

The pottery included in the study is all clearly identifiable as Kiukainen or Pyheensilta Ware (Figs. 3–5). Identification of the pottery was based on decorated fragments to ensure reliability. All pottery fragments in the collections that met the identification criteria and were assessed to contain sufficient carbon deposits for dating were selected for this study. However, not all fragments could be dated, as some had too low or contaminated carbon content. The material other than pottery which is dated here originates solely from contexts that can be attributed to the Kiukainen culture or the Pyheensilta group. Other samples than pottery have not been collected from multiperiod or multicultural settlement sites.

RESULTS

Pyheensilta group

All 16 datings of the Pyheensilta group together form a timeline, beginning at 4551 BP (before present, i.e., 1950 CE) and ending at 4119 BP (Fig. 6). When calibrated, the timeline ranges from 3369–2578 BCE with 95.4% probability and 3364–2622 BCE with 68.4% probability.

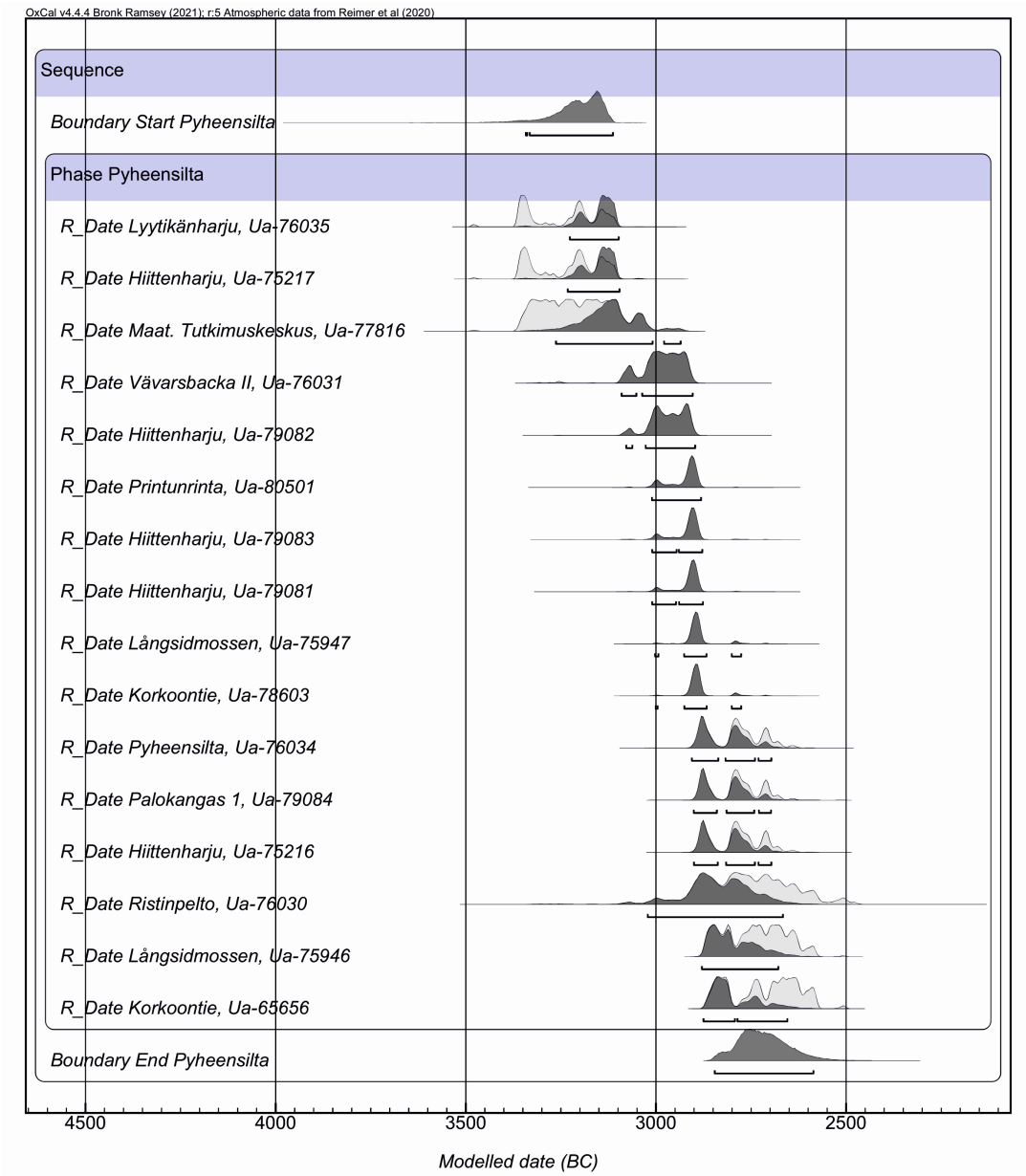


Figure 6. Dated material and probability distribution of calibrated samples from the Pyheensilta group. For details and references, see Appendix 1.

After Bayesian modelling, the most likely period for the Pyheensilta group is 3200–2650 BCE. When examined individually the datings appear to form two almost separate groups, but the modelling reduces the differences. There are no remarkable single deviations, and neither the earliest nor the latest dating is far from the next closest. Calibrating samples into calendar years introduces some uncertainty, as the margin for individual samples can be about three centuries. Also, the calibration curves affect the picture as they are very similar when the ages of the samples are close.

The oldest dating, from Lyytikänharju site in Harjavalta 4551±30 BP (Ua-76035), is from charred crust in the pottery and the reported $\delta^{13}C$ (‰) value for the sample suggests it contains only terrestrial carbon. The exact

discovery elevation in metres above sea level (masl) of the pottery fragment is not available, but the highest limit of the cultural layer is reported to have been at 38.44 masl (Meinander 1955). The discovery elevation does not conflict with the dating, as the second oldest dating 4542±30 BP (Ua-75217) was found at a similar elevation on the adjacent Hiittenharju site (Soisalo & Väisänen 2022). This sample is burnt bone, perhaps with old wood effect. Determining ancient sea level in the area with a precision of a century is difficult, and accurate data are not readily available. Sea level in Pori on the current coastline varies by approximately ± one metre depending on wind and atmospheric pressure (https://www.ilmatieteenlaitos.fi/vedenkorkeustilastot). It can be assumed that the variation in the area was roughly the same or more 5000 years ago. Using the topography of the site and the rate of land uplift 7 mm per year, only a general overview of the chronology can be determined. A burnt bone sample 4207±31 BP (Ua-79084) from Palokangas at 38 masl is available and was collected from the lowest part of the site. Considering the discovery elevation, it would be safest to interpret the calibration curve of the Lyytikänharju sample as representing a time frame mainly between 3216–3121 BCE, with 37.4% probability. The third early dating is charred crust from pottery found in Vantaa 4533±32 BP (Ua-77816). The sample shows signs of MRE and when modelled, its dating is 4492±52 BP, which does not much alter the result.

The youngest dating is from Espoo Korkoontie, 4119±30 BP (Ua-65656). Calibrated, the sample ranges from 2864–2578 BCE with 94.5% probability and 2855–2622 BCE with 68.2% probability. The second youngest is from charred hazelnut from Långsidsmossen in Kimitoön 4142±32 BP (Ua-75946). Calibrated, the sample ranges from 2874–2584 BCE with 94.5% probability and 2864–2632 BCE with 68.2% probability. The discovery elevations, topography and other datings from these two settlement sites support interpreting the samples towards the older end of the calibration curve. Taken together the samples discussed in this study form a series representing the time span of the Pyheensilta group. Based on the results, I propose dating the Pyheensilta group to approximately 3200–2650 BCE.

Kiukainen culture

The datings of the Kiukainen culture fall between 4003 BP and 3415 BP (Appx 2; Fig. 7). They do not form clear clusters but are rather evenly distributed across different centuries. Overall, datings related to the beginning and the end of the culture require further clarification and understanding, especially of their MRE values. Generally, many of the samples taken from charred crust of pottery have clear signs of MRE. When calibrated, the datings of these samples are less precise, making their comparison challenging, although the uncalibrated results do not change much in relation to them. (see Appx 2 for details).

Turku Kotirinne (Ua-45726), MRE modelled 3944±58 BP, is the oldest dating of the Kiukainen culture. Bayesian modelling gives many datings around this period, with low variation. Based on these results, the Kiukainen culture seems to begin at earliest around 2500 BCE. The oldest settlement sites are Turku Kotirinne, Kristiinankaupunki Lappfjärd and Harjavalta Kraakanmäki 1.

Datings from the end of the Kiukainen culture are similarly challenging. MRE introduces imprecision into the two youngest results from the pottery. However, the known $\delta^{13}C$ (‰) values of the samples facilitate evaluation of the results. A charred crust from pottery from Jordbro in Kemiönsaari modelled 3485±68 BP (Ua-78068), a moderately good result specifically for dating the use of Kiukainen Ware. Charcoal datings from pottery discovered in Ölmosviken in Kemiönsaari 3511±30 BP (Ua-66817), 3520±30 (Ua-67826) and charred hazelnut from Kirkkokangas IV in Pori 3514±31 BP (Ua-72798) align with the same period. The youngest dating which can be associated with Kiukainen culture is from Turku Riihivainio 3440 BP±35 (Hela-3084) and is from charcoal collected from cultural layer which yielded only Kiukainen culture finds. The sample's calibration curve is broad, and the model deprecates it. Based on these datings and Bayesian modelling, the

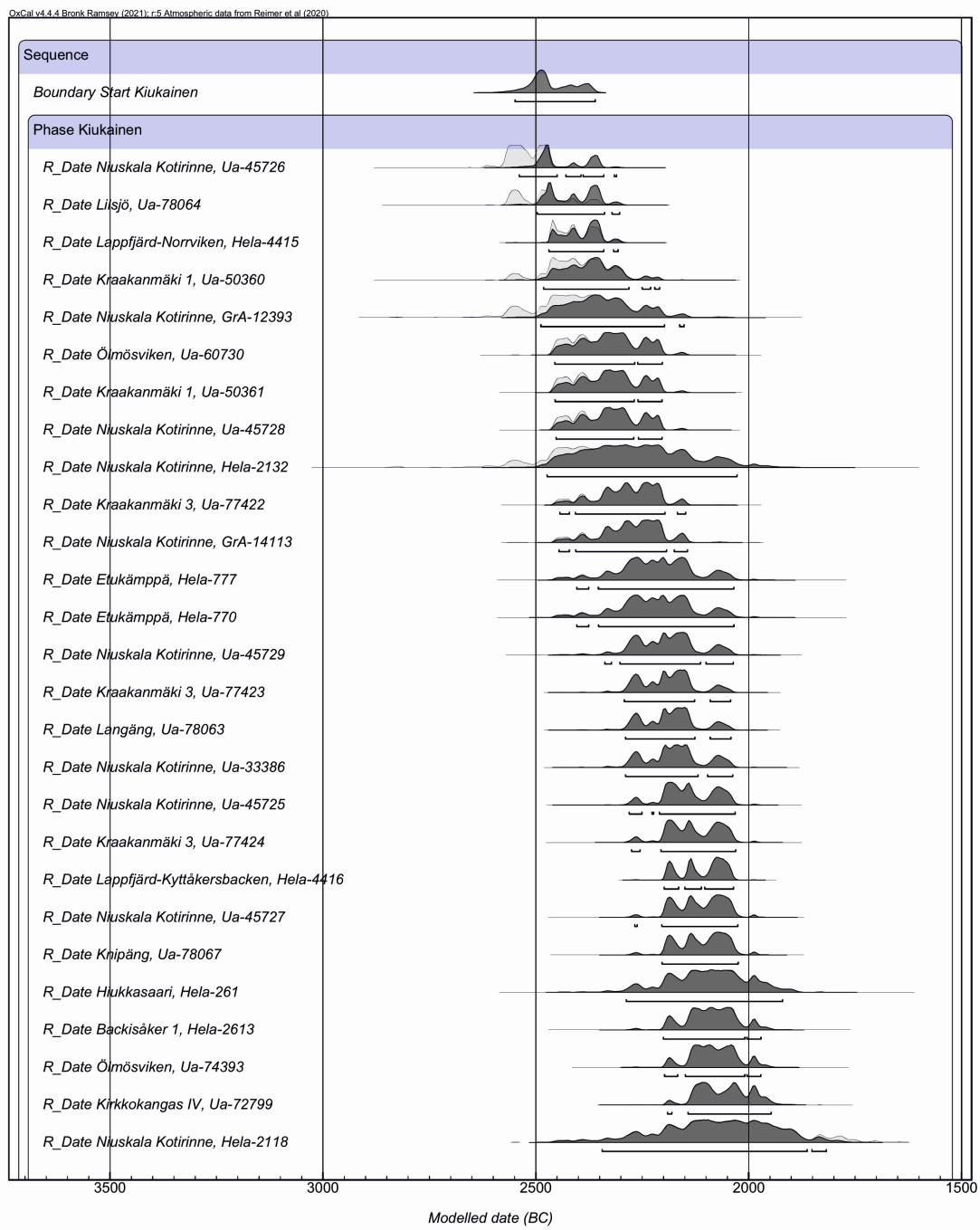
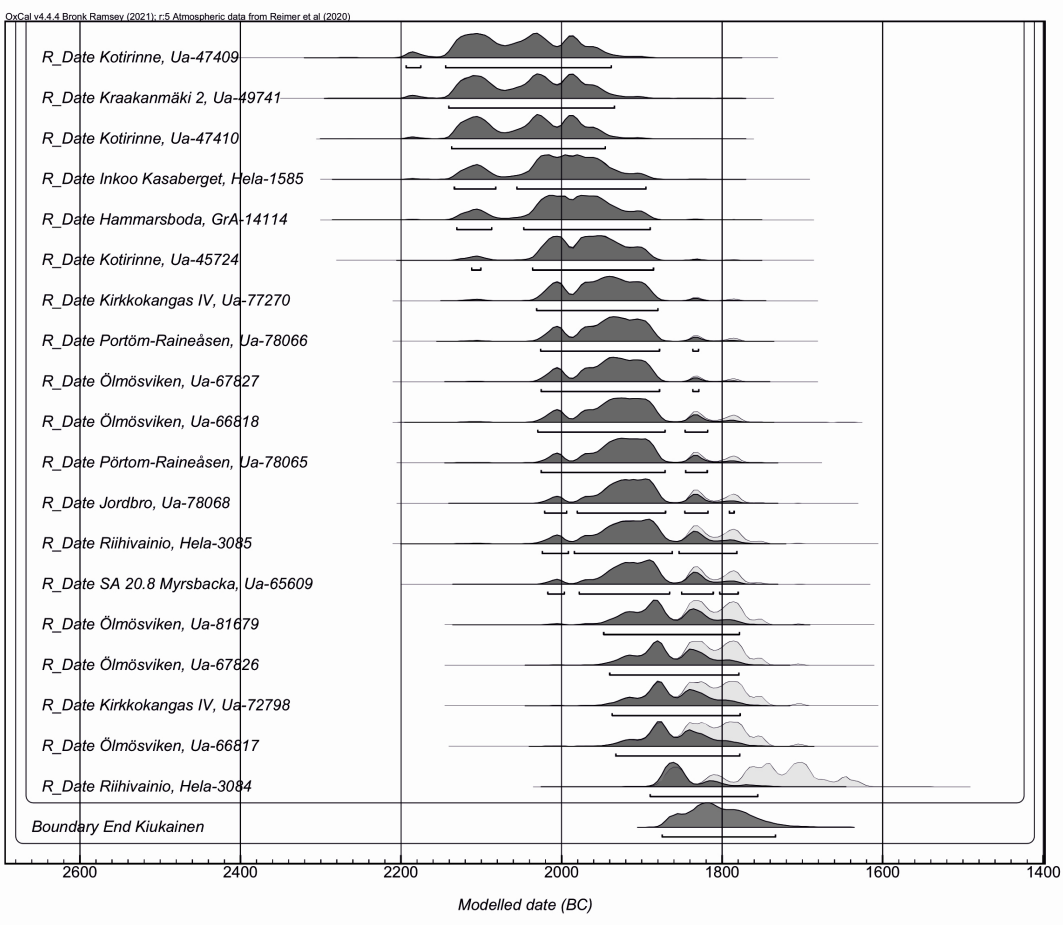


Figure 7. Dated material and the calibration curves of the older datings of the Kiukainen culture. For details and references, see Appendix 2. The figure continues on the next page.

Kiukainen culture dates approximately 2500–1750 BCE. This means that there is a gap of 150 years between the Pyheensilta group and the Kiukainen culture.

DISCUSSION

The results of the study help us to understand late Stone Age developments on the northeastern



Baltic coast and provide a solid foundation for further research. Radiocarbon dating always involves uncertainties, and the results must be interpreted with caution. In this study, efforts were made to reduce error margins by paying attention to MRE and utilising Bayesian modelling. Excluding inaccurate samples, considering MRE, and Bayesian modeling expanded the difference between Pyheensilta group and Kiukainen culture. However, the gap between the groups is still evident without modeling, and based on these samples, the groups are not overlapping. The modeling of the Kiukainen culture practically led to the same result as the previous ^{14}C-based study (Pesonen 2021). The end of the Kiukainen culture is somewhat open to interpretation, and out of caution, I have slightly extended it. According to the curve, it could also be ending as early as 1800 BCE.

The importance of MRE modelling is emphasised when dating the charred food residues on pottery from coastal Stone Age cultures. Five pieces of pottery from the Pyheensilta group were dated, two of which showed evidence of MRE based on δ^{13}C values. Their significance to the overall picture is not decisive, but the situation is different regarding the Kiukainen Ware. Out of 25 fragments with known δ^{13}C values, 21 contained varying amounts of marine carbon. Many contained so little MRE that it had only a small impact even on individual dating. Bayesian modelling was important in dating for both cultural phases and it stabilised the results. For the extremes in the datings, it also reduced the possible impact of the MRE and other possible inaccuracies.

The end of the Pyheensilta group is also somewhat difficult to interpret. The boundary

end curve declines steadily from 2700, and by 2600 the Pyheensilta group has disappeared. For this reason, I suggest that the Pyheensilta group ends around 2650. It is also important to consider the relatively small total number of samples in the interpretation, so the dating of the Pyheensilta group may become more precise in the future with new (^{14}C) samples. Additionally, entirely new settlement sites dating to the later period of the group may still be discovered.

The early Pyheensilta group

Based on this study the Pyheensilta group is estimated to have begun around 3200 BCE. This coincides well with the disappearance of the Late Comb Ware culture in the same coastal area, 3195±100 BCE (Pesonen 2021). Precise dating of the cultural changes is difficult, as radiocarbon dating always involves inaccuracies, and the number of datings is small. Pyheensilta Ware was found at only a few Late Comb Ware sites, even though there is not much chronological difference between them. Three of the datings are from settlements that were inhabited during the Late Comb Ware period. Vantaa Maatalouden tutkimuskeskus 3360–3026 BCE, is the oldest of these three, which suggests that there were inhabitants at the site soon after the disappearance of the Late Comb Ware culture. In the context of this study, it is impossible to assess whether a new population using Pyheensilta Ware had entered and settled in the area.

This easily leads to the question: to what extent do changes in material culture reflect demographic shifts? Change from Late Comb Ware culture to the Pyheensilta group can be considered at least a cultural, if not also a demographic turning point, as the material culture of these two traditions differs in many ways. The decoration and shape of the pottery changes so much that a direct continuity between traditions is hard to see. At the same time almost all settlement sites were abandoned with the decline of the Late Comb Ware culture, and archaeological material decreases sharply. The use of pottery also appears to change, as Pyheensilta Ware is usually found only in very small quantities, as at Vantaa Maatalouden tutkimuskeskus.

The dating of the Pyheensilta group is quite similar to that of the Pöljä group (3300–2500 BCE; Nordqvist & Mökkönen 2021), which was present in the lake area of present-day central Finland, on the northern coasts of the Gulf of Bothnia and some parts of the northern coast of the Gulf of Finland. These two groups share many similarities in their material culture, such as long arrowheads made of slate. Their pottery also resembles each other in terms of shape and decoration. The most distinctive feature is the asbestos temper in Pöljä Ware, which defines the entire pottery style and cultural group (Meinander 1954a: 162–165). Pöljä and Pyheensilta Ware have been found at several of the same settlement sites, indicating close connections between these groups (Vikkula 1987; Fast & Soisalo 2020). The contemporaneity and partially overlapping distribution of these two groups may explain many similarities in their material culture, but there were also similarities in their ways of living, especially along the coast. Communities using Pöljä Ware on the coast of the Gulf of Bothnia practiced maritime hunting and fishing and lived mostly at river mouths. From these settlements in Ostrobothnia many house pits have been found, and they were organised as small villages (Skantsi 2023: 138–140). The house pits at Harjavalta are so similar in shape and size that it can be assumed that the houses themselves were like those of the Pöljä group. Many similarities between these two contemporaneous groups suggest a common origin or at least close contact between these communities.

The end of the Pyheensilta group and beginning of the Kiukainen culture

Based on the datings, the Pyheensilta group fades around 2650 BCE. The CWC, spreading from the Baltics from 2850 BCE onward (Pesonen et al. 2019), settled roughly in the same area as the Pyheensilta group, which disappeared approximately 200 years after the CWC arrived. The Pyheensilta group and the CWC had different subsistence strategies, but little is known about their interactions. The

subsistence of the CWC in Finland was at least partly based on pastoralism (Cramp et al. 2014; Ahola et al. 2018; Pääkkönen et al. 2019). Small-scale farming is possible, but there is no direct evidence of that so far. Nevertheless, many of these two group's settlements were located close to each other, and the occurrence of both pottery styles at numerous sites suggests connections between the groups. Without datings, however, their contemporaneity at the same settlement sites remains unproven.

Events in 2650–2500 BCE can be approached by studying the sizes of different populations during that time. An estimation of the CWC's population size can be carefully derived from the number of known CWC settlements. In 2012, a total of 357 settlements were identified based on pottery, though this number has since increased (Nordqvist & Häkälä 2014). Nearly all sites are multiperiodic and the scarcity of purely CWC settlements complicates assessment. Furthermore, a few pottery sherds make it difficult to evaluate the size of a settlement. The issue is further complicated by the different preservation characteristics of pottery styles. The Corded Ware preserve better due to different manufacturing techniques, and it is also easier to identify compared to the Pyheensilta Ware. Anyway, the number of CWC settlements is notably higher than the 69 known settlements of the Pyheensilta group, which were similarly defined by using pottery. Based on datings, the CWC partly overlapped with the Pyheensilta group, as 11 out of 17 dates coincide with the Pyheensilta period (Pesonen et al. 2019). Later, CWC dates also decline, but they continue even after the formation of the Kiukainen culture. Interestingly, the three datings clearly contemporaneous with the Kiukainen culture are not from Southwest Finland, but from farther east along the Gulf of Finland coastline (Pesonen et al 2019).

There seems to be a chronological gap between the Pyheensilta group and the Kiukainen culture. Pyheensilta groups dating's end at 2650 BCE, and the Kiukainen culture begins around 2500 BCE. Somewhere between these years, archaeological traces of the Pyheensilta group disappear, and the Kiukainen culture appears. Did the Pyheensilta group simply vanish, merge into the CWC communities, or receive influences from the CWC as the Kiukainen culture began to form? It is difficult to answer these questions based on datings alone, but the changes seem to occur particularly in communities living on the coasts, and the CWC appears to undergo little change during these centuries. This indicates that the cultural transition happened only in coastal communities, which likely encountered both cultural and demographic upheavals during this time. Similar events are known elsewhere in Europe where the CWC spread, resulting in the disappearance or changes in the material culture of prior populations (Beckermann 2015; Allentoft et al. 2024).

Cultural development was not uniform along the Baltic coastline after the CWC spread. In present-day Sweden and Åland, its appearance led to the development of the Fagervik III style of Pitted Ware into the Fagervik IV style, characterised by flat-based vessels and decoration heavily influenced by the Corded Ware. However, there are no signs of population decline or reduction in archaeological material during the same period in Åland, although a similar decrease in population around 2500 BCE has been noted in southern Sweden, Norway, and Denmark (Nielsen et al 2019). In Estonia and Latvia, the arrival of CWC apparently did not lead to the complete disappearance of local communities, mainly Late Comb Ware ones; instead, they are believed to have continued existing until the beginning of the Bronze Age (Kriiska 2020; Bērziņš 2021).

Finds from the Kiukainen culture were first dated in its core areas. The culture seems to have formed nearly simultaneously in the estuary of the Kokemäki River, the Kristiinankaupunki Lappfjärd area and the Turku region. All these sites were inhabited during the Pyheensilta period and had CWC settlements, indicating possible population continuity over the 'silent' centuries for which we have no archaeological record. On the coasts, the Kiukainen culture seems to partially continue the maritime lifestyle of the Pyheensilta group, but with significant changes in material culture that likely reflect alterations in other aspects of community life. The Kiukainen culture is not yet well understood, so it is challenging to determine from the finds whether certain materials clearly

mark the beginning or end of this cultural phase. The only significant change in the material culture is with the onset of Kiukainen culture. Could this also be when small-scale farming and animal husbandry were adopted, possibly from CWC, even though clear evidence of them appears only centuries later?

Most finds were dated to the final centuries of the Kiukainen culture, from 2200–1750 BCE. This is partly due to many settlements in this study are from that period, including many settlements for which we have only one dating. The concentration of datings in this period may indicate a larger population and thus better archaeological visibility. The CWC appears to have been partly contemporaneous with the Kiukainen culture, but it disappeared from at least the coastal areas by 2200 BCE (Pesonen et al. 2019). Sudden cooling of the climate in this period, especially during winters, has been observed (Helama & Oinonen 2019). The cooling of the climate around 2200 BCE may have posed challenges for CWC agriculture. Remaining CWC communities may have also been absorbed into the Kiukainen culture.

The end phase of the Kiukainen culture

Based on these datings, the Kiukainen culture ends around 1750 BCE. This aligns well with the shift from the Stone Age to the Bronze Age on the northeastern Baltic coast (Lavento 2015). It is not a clear singular event, as datings decrease before the beginning of the Bronze Age. This suggests a rapid change in cultural landscape or a drastic decrease in population (Tallavaara et al. 2010; Lang 2020: 249). One reason for the scarcity of finds could be the diminishing significance of marine hunting and the increasing importance of agriculture during this period. Marine hunting involved extensive use of pottery for storing catches and quartz and porphyrite tools needed for processing prey. As the use of these items decreased, so did the archaeological findings, as most of the finds from Kiukainen culture settlements are quartz and porphyrite flakes and fragments of pottery.

The first evidence of Kiukainen people being involved in agriculture is from Riihivainio, Turku in 2191–1880 BCE (Lempiäinen-Avci et al. 2024). Domesticated animals were kept during the Kiukainen period, although it is difficult to determine their importance for the subsistence due to the limited findings. Sheep or goat finds were made near the northern limit of the Kiukainen area in Ostrobothnia, Kvarnabba where a burnt bone dates 2200–1950 BCE (Ua-43043; see Bläuer & Kantanen 2013). From Åsgårda on the Åland islands, there are datings of cattle to 2341–1937 BCE (Ua-10689) and a sheep to 2401–1887 BCE (Ua-11460; see Storå 2001). The cattle tooth dated 1941–1749 BCE (Ua-81679), recently found at Ölmosviken is the first evidence of cattle at a Kiukainen culture settlement in mainland Finland (Nurminen 2024a). The increasing significance of early farming is archaeologically challenging to detect. Apparently, at the end of the Kiukainen period, there was a more noticeable shift from larger Stone Age communities to smaller-scale farming-based settlements in the Bronze Age, coinciding with a decrease in archaeological traces.

Apparently, the use of Kiukainen Ware did not continue as far into the Bronze Age as previously thought (Meinander 1954a: 183; Edgren 1984: 95; Salo 2004: 123; Lavento 2015: 192). The clarification of the issue would require more (^{14}C) samples of Kiukainen Ware from settlement sites where habitation may have continued into the Bronze Age. So far, the beginning of the Bronze Age appears to be a very quiet period along the present-day Finnish coast, and based on archaeological findings, population increases only during the Montelian II period starting in 1500 BCE. The very few radiocarbon dates from Bronze Age Paimio Ware or it find contexts are from the end of the Early Bronze Age or the beginning of the Late Bronze Age 1400-800 BCE (Asplund 2008: 206). It seems to be that pottery use and function changed with the onset of the Bronze Age. The radiocarbon dating presented here suggests that this change was rapid and comprehensive, transforming not only material culture but also ways of living.

Bronze Age culture was introduced to the Kiukainen culture through maritime connections and migration from nearby Southern Scandinavia, (Meinander 1954b: 196–197; Salo 1981; Huurre 1991: 107; Carpelan 1999: 27; Lavento 2015: 198–199;

Lang 2020: 201). Western ties were not new as Åland had been in close contact with Southern Scandinavia since the Middle Neolithic period. These contacts continued during the Kiukainen period and were not limited to Åland, but also brought flint, flint objects and shaft hole axes from Scandinavia to the coasts of the Finnish mainland. Despite intensive interactions, the Kiukainen culture clearly differed from the Late Neolithic culture of Scandinavia and retained its uniqueness. Based on contacts and interactions, The Bronze Age began on the coasts of Finland only a little after it did in Sweden, which is dated to 1800/1700 BCE. The beginning of the Bronze Age in the coastal areas of Finland is poorly understood, partly due to the scarcity of finds, and still requires much new research. With this, the picture of the end of the Kiukainen culture will surely become clearer.

CONCLUSIONS

This study elucidates the chronological framework and cultural succession of Neolithic populations on the coastlines of present-day Finland through radiocarbon dating. The findings demonstrate that the Middle Neolithic Pyheensilta group existed from approximately 3200–2650 BCE, followed by the Late Neolithic Kiukainen culture from about 2500–1750 BCE. The 150-year gap between these two cultures suggests a period of cultural change and possibly low population living on the coast. The Kiukainen culture emerged about 300 years before the final disappearance of the CWC, so the communities belonging to these cultures coexisted in southern Finland for at least two or three centuries. Despite the formation of the Kiukainen culture, some of the CWC communities apparently continued their existence and preserved their material culture.

These results provide valuable insights into the complex dynamics of cultural development and transition in Neolithic Finland, highlighting the importance of precise chronological frameworks in understanding the region's archaeological record. Further research is needed to explore the nature and causes of the quiet period between the Pyheensilta group and the Kiukainen culture and the role of the CWC in this process.

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Nikolai Paukkonen

USING COMPUTER VISION TO DETECT AND CLASSIFY ARCHAEOLOGICAL FINDS FROM TURKU MARKET SQUARE EXCAVATION

Abstract

Modern computer vision technologies allow for the automatic detection and classification of objects visible in digital images. Robust applications in the context of archaeological remote sensing have already been presented, both in Finland and abroad. However, using these methods to detect and classify smaller objects is still only partially explored. In this paper, I examine the potential of using a modern open-source YOLOv11 model for archaeological find detection and classification. Training material has been collected from the large-scale Turku Market Square (Kauppatori) excavation (conducted between 2018 and 2022) and includes a wide variety of find types from the Early Modern Period. The results show great potential for using automated object detection with archaeological find material. Practical applications of this method could lead to significant labor savings in processing find material from large-scale excavations.

Keywords: Artificial intelligence, computer vision, digital archaeology, digital humanities, Finnish archaeology

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INTRODUCTION

For a few decades, artificial intelligence, machine learning, and various computer vision applications have been applied to archaeological data. The main applications of computer vision approaches have been in the fields related to GIS and remote sensing and have been especially concerned in finding and classifying new sites (e.g., Engel et al. 2019; Jamil et al. 2022). Perhaps the most known use cases have been in automatically scanning the jungles of Central America or Southeastern Asia for remains of human habitation (Kokalj et al. 2023), but computer vision and remote sensing have also been combined in Finland to detect potential sites in large areas automatically (e.g. Seitsonen & Ikäheimo 2021; Anttiroiko et al. 2023). Experiments on smaller scale objects have been performed, but computer vision methods are yet to be established in subject areas such as archaeological find processing.

The aim of this study is to examine the usefulness of computer vision approaches in detecting, identifying and classifying archaeological find material. Archaeological find assemblages usually consist of various find types. For example, an excavation of an Early Modern (1500s to early 1800s) site might yield fragments of pottery, glass, white clay pipes, coins, bones, leather, wood, metal objects and many other more rare types. Detecting and identifying these kinds of objects using computer vision entails several problems. The morphological variance within these types may be wide: for instance, pottery fragments come in many shapes, sizes and colors.

The appearance of the finds also depends a lot on their state of preservation, the geochemical context where they were deposited, and so forth. The consistency, hardness, weight and even smell may be deciding factors when an archaeologist is making a semi-intuitive decision on what the find in their hands actually is. A human would never make a mistake between a piece of rusty iron and a darkened pottery fragment, but is it possible to train a machine to attain the same certainty based only on digital 2D images?

An affirmative answer to this question would have wide-ranging implications. A lot of modern excavations are conducted in urban environments, where the amount of so-called mass finds can be enormous. Possibilities of automating some of the processes related to find processing would have undisputable value. Furthermore, archived digital photographs that have no comprehensive metadata could be sorted and analyzed retrospectively – this could help researchers specializing in certain artefacts to quickly categorize large digital archives for their own use cases.

In this article I examine and test a machine learning based approach to automatic archaeological find detection and identification. The main content is based on training, validating and testing a YOLOv11 model using digital photographs of the finds made during Turku Market Square excavation, conducted between 2018–2022 (Fig. 1). As arguably one of the largest and most complicated urban excavations ever done in Finland (Uotila 2024), it offers a great source of training material for a computer vision model intended for use with find material from Early Modern period.

BACKGROUND

The main task of automated object detection is to locate and classify objects visible in the target

Figure 1. A drone photo of Kauppatori excavation in full swing, looking south (Muuritutkimus Oy).

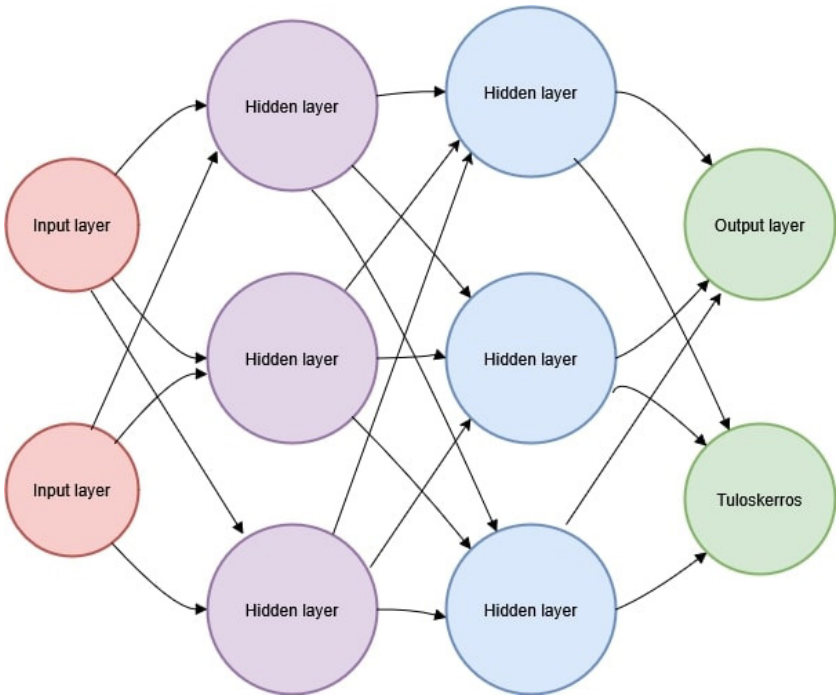

Figure 2. An example of a simple neural network, where edges connect neurons of different layers. Data enters the network through the input layer, gets processed in the hidden layers and is then sent to the output layer.

image or video frame (Liu et al. 2021). This is achieved by drawing a so-called bounding box around the objects that have been detected and then yielding a probability value for the predicted class of the object. Alternatively, the detected object can be delineated following its pixels. Object detection differs from image detection, where the idea is to recognize what the whole image is depicting, instead of discerning possible multiple objects from it. A special case of object detection is small object detection, which is used for e.g., self-driving car guidance systems or industrial quality control equipment (Nguyen et al. 2020). Automated object detection is based on applications of machine learning.

Machine learning

Artificial neural networks (ANN) are the central technology behind all object detection based on machine learning and deep learning. Originally ANNs were built to imitate neurons and their connections in human brain, but eventually their development has separated from this aim (Gurney 2003). A neural network is based on nodes (or neurons), connected to each other with edges, which are ordered in layers (Fig. 2). These layers are called input, hidden, or output layers, depending on their function in the network. Nodes in these layers transfer data through weighted edges, as can be seen in Figure 2. The input received by the nodes could be for example a pixel from the image being processed, that would travel through the hidden layers and activate nodes in the output layer accordingly.

Most of the modern object detection approaches are based on convolutional neural networks (CNN), the basis of which was developed already in the turn of the 70s and 80s (Fukushima 1980; Goodfellow et al. 2016). When an image is being processed with a traditional ANN, where all the neurons between adjacent layers are connected, the number of weighted edges grows exponentially, making the system slow and cumbersome. In a CNN, not all nodes are connected with each other, but they instead use matrix-based filters or kernels (Goodfellow et al. 2016: 320). A CNN has so-called convolution layers and pooling layers in addition to the input, hidden and output layers, which are still fully connected with each other (Goodfellow et al. 2016: 341–342).

A neural network used for object detection must be trained using material that corresponds to the kind of material that is to be identified and classified by the network when it is operational.

In this case, this would mean training the model with the kinds of archaeological finds that it will be expected to identify. Through training the edges are weighted to produce suitable classifications. This means that during training, the system adjusts the importance of connections between nodes to optimize classification accuracy. Object detection usually uses backpropagation algorithm, which can be utilized to count these weights and thus the results of the activation. Training the neural network usually requires multiple iterations over the training data, with each pass gradually improving the results. A complete pass over the whole training dataset is called an epoch, and typically dozens of epochs are required for the model to reach optimal performance (Goodfellow et al. 2016: 208–214, 244–246).

The data used to develop a neural network is typically divided into three subsets: training, validation, and testing data. The training data is used to adjust the network's weights and biases, enabling the model to learn patterns and improve classification accuracy. The validation data is separate from the training set and is used to tune the parameters and monitor performance during the training process. Finally, the testing data is an independent dataset that is used to evaluate the final model's real-world performance.

Evaluating machine learning models

In object detection and machine learning applications in general there are few different methods of evaluating the functionality of the model. Of these, the two most important ones are precision and recall (Goodfellow et al. 2016: 406–407). Precision can be calculated as follows:

Precision = Relevant retrieved instances / All retrieved instances

Precision compares the number of correct identifications with the number of identifications all together (including false ones), but it does not tell anything about the possible objects being missed completely. Recall, in turn, takes into account the number of objects that were available for detection:

Recall = Relevant retrieved instances / All relevant instances

The difference between precision and recall can be illustrated with an example. Let us imagine a set of images, where there are 10 pieces of glass and 10 pieces of pottery to be detected. The program detects 8 pieces of glass correctly and additionally detects 4 pieces of pottery as pieces of glass erroneously. As such, the precision value will be 8/12 = 0.66… and the recall value 8/10 = 0.80.

Both values are relevant for the end result: precision measures the model's ability to find only relevant objects, whereas recall measures its ability to find all the relevant objects available (Padilla et al. 2020). In addition to these values, it is common to calculate a mean average precision (mAP) for the results. This value is often used when comparing different object detection models with each other (Padilla et al. 2020). MAP is based on an average precision (AP) calculated from all the different classes that are to be detected by the model. It is calculated for every class using their precision and recall values and then using different threshold values for how well the estimated bounding box lines up with the real bounding box (intersection over union, IoU). The curve visualizing AP can be calculated with for example 11-point interpolation method (Padilla et al. 2020).

Regardless of the method used to calculate AP, the resulting curve will visualize the relationship between precision and recall: AP is high, when the results have good values for both. However, AP becomes low, when either one of the two is low. MAP in turn is used as a summary of the AP of all classes to be detected. In other studies that used standardized training materials, the mAP values are often around 0.7 to 0.9 (Liu et al. 2021; Sharma et al. 2024).

In addition to these most commonly used numerical metrics, the reliability of a model can be estimated using a so-called confusion matrix. In it, the columns of the matrix represent real classes, whereas the rows represent the detections in the classes. Confusion matrix is especially useful when one wants to portray which classes are commonly mixed up by the model.

The risk of overfitting is good to mention in the context of these reliability metrics

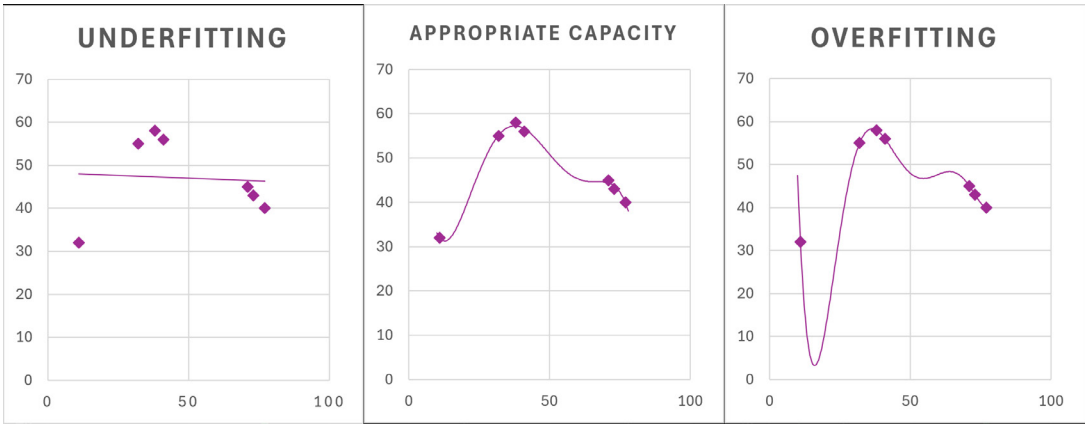

Figure 3. Example diagrams depicting overfitting. The points represent observations used for the training of the model, whereas the curve represents the prediction made by the model. On the rightmost case the model suffers from overfitting, because the dip between the first two points does not represent the actual relations between the training observations, even though it otherwise seems to follow the points accurately. Similarly, the leftmost diagram shows a case of underfitting, where the model is too simple for its prediction to be of any real use. (Goodfellow et al. 2016: 108)

(Goodfellow et al. 2016: 105–108). It can occur if the training material is too one-sided in relation to the natural variation of the object types that it is intended to be detected. The model may work seemingly well with the training material but may still fail completely when encountering familiar objects in new environments, which is also visualized in Figure 3. For example, we may imagine an object detection model trained to detect coins based on training material of images with coins only with a black or dark background. Due to overfitting, it would not work in cases where the background is of light color.

You Only Look Once (YOLO)

One of the most used object detection algorithm families is the You Only Look Once -series (YOLO). Its first version was published already in 2016, but it has seen multiple iterations since by various developers (Redmon et al. 2016). One of its main advantages is the option for fast real-time detection, and overall, YOLO offers a good compromise between speed and reliability. Furthermore, most of the YOLO versions have been published with open-source licenses. The idea of the original model was to be functional with all kinds of visual input, which makes it a potential choice when trying to detect archaeological find material.

YOLO works by shrinking the input image into a smaller format, which is further divided into N x N squares. For each square a probability of there being any object at all is calculated. Finally, a location and a class-specific probability is calculated for each square (Redmon et al. 2016). For each bounding box the model estimates x and y values, which depict the location of the center of the box in the image. Additionally, h and w values are estimated, which determine the height and width of the bounding box. A pc value is the probability that there is some object inside the bounding box, and $C_1 \ldots C_n$ present the various pre-trained classes that the model is intended to detect and classify.

$$y = [p_c \;\; x \; y \; w \; h \; C_1 \ldots C_n]^T$$

The end result can be visualized with a picture that contains the bounding boxes, the classifications and the values for the probability of the classification to be correct. An example can be seen in Figure 4.

YOLO models have their weaknesses, and especially the older versions were subpar in locating the objects accurately and detecting extremely small objects (Redmon et al. 2016; Jiao et al. 2019). However, already in YOLOv3

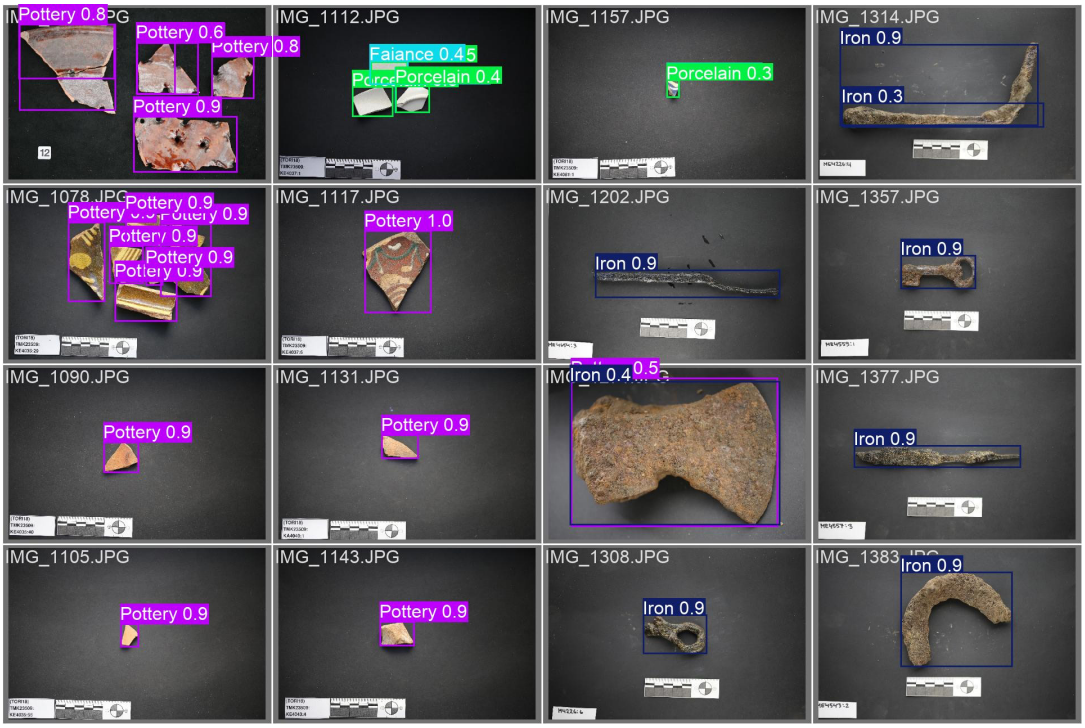

Figure 4. Resulting frames from images detected by a YOLOv11 model trained for this paper. On the upper corner of a bounding box the class name is visible, in addition to the probability of the classification (in the range of 0.0 – 1.0). Different classes have bounding boxes of different colors.

its capabilities were greatly improved through changing the input image size (Redmon & Farhadi 2018). The version used for the purposes of this paper, YOLOv11 (published in September 2024), is already very advanced compared to the original model. Although it is still based on the same principles as the original version, its architecture is slightly different. It is divided into layers called backbone, neck and head – of these, backbone is used to identify features from the input image in multiple different scales. Neck is used to combine these identifications together, from where the data is transferred to head, where the final locating and classification decision is made far more effectively compared to earlier YOLO versions (Khanam & Hussain 2024).

Overall, the differences between various iterations of YOLO are small, and usually their key advancements have been adding or modifying singular related technologies. This is confused by the fact that their developers try to market their innovations as game-changing and important. Regardless, multiple comparative studies show that newer YOLO versions are significantly faster and more reliable than their predecessors, and often also better than non-YOLO solutions, such as the R-CNN family of machine learning models (Region Based Convolutional Neural Networks) for object detection (Khanam & Hussain 2024; Sharma et al. 2024).

Object detection in archaeology

Object detection methods have been used in archaeology increasingly starting in the 2000s. In remote sensing applications they have been used to locate and identify new sites of interest or to monitor the status of known archaeological heritage in remote or dangerous areas. For object detection in archaeological remote sensing, much has already been published (e.g., Traviglia et al. 2016; Seitsonen & Ikäheimo

2021; Marçal et al. 2024), and it can be said that object detection has become a regular tool for this kind of research and work. Most commonly this type of work uses CNNs and their applications (Amirah Hanani Jamil et al. 2022). However, using object detection and smaller and nearby targets are still issues that are only being developed and tested for archaeology.

Detecting and identifying surface finds from image-based material has been researched before. A typical application would be supplanting or supporting field walking with drone-based image collection, which is then processed using machine learning. Hector Orengo and Arnau Garcia-Molsosa have developed a method, where drone-photogrammetry based RGB orthoimages are used with specially trained object detection model to find concentrations of pottery fragments on open fields (Orengo & Garcia-Molsosa 2019). Similar research has been done by Argyro Argyrou and others (2023) on Cyprus. Problem with both projects is the restricted use cases for them: for instance, the model trained by Orengo and Garcia-Molsosa (2019) detects pottery fragments on fields that are similar to the ones where they have been trained but start to yield erroneous results when the color of the soil changed. Additionally, both models were limited to detecting only common red-ware pottery, and could not detect any other types of finds.

Object detection applied for archaeological material has been studied also in marine contexts. A prototype utilizing YOLOv8 model was able to detect underwater pottery fragments from live feed of a remote-controlled underwater drone with moderate accuracy (Paraskevas et al. 2023). Since underwater archaeology poses significant hazards compared to surface work, it is clear that this kind of application would have a great impact considering work safety by decreasing the need for the use of human divers.

One important research direction has been the use of machine learning in automating the study of old research reports. For instance, the AutArch software, developed by Kevin Klein and others (2023; 2025), interprets reports written in different countries and different languages and detects and delineates maps, plans and drawings in them using a Faster R-CNN neural network. However, it does not classify find types depicted in the reports.

Detection and classification of multiple find types through object detection models has not been studied extensively in archaeology. Some work has been done in classification of various pottery typologies, typically using CNNs (for example Ling et al. 2024), However, the interest has been generally in very fine-grained classification of smaller typological groups inside one find type or the variance related to the ceramic fabric (for example Liu 2023).

A typical feature in archaeologically inclined publications on the topic of object detection is that the theoretical background behind the methods used is not explicated extensively. For example, Oula Seitsonen and Janne Ikäheimo (2021) mention in their article that they use CNNs, but that the analyses have been done on commercial platform Picterra. This kind of black-box thinking is understandable, since machine learning applications are often complicated and may require a specialist to support the research team (Jamil et al. 2022). Object detection applications can already be trained and deployed using packages equipped with graphical user interfaces (GUI) and cloud-based computing, so the threshold for simple usage is not very high. For instance, ChatGPT's CNN-based object and image detection function is very easy to test on a regular Internet browser (e.g., Gill & Kaur 2023; Osco et al. 2023; Driessen et al. 2024).

Based on this overview it seems evident that object detection and computer vision have not been used very much in detecting and classifying complex archaeological find assemblages. The following experiment and results act as a new opening for future discussion.

DESIGN OF EXPERIMENTS

The experimental part of this article investigates the possibility of developing a program that can detect and classify archaeological finds of different types based on digital images. The aim is to train a YOLOv11 model that can classify find objects visible in any input picture quickly or in real time. Further applications could include automatic compilation of find statistics, cataloguing archival find images or

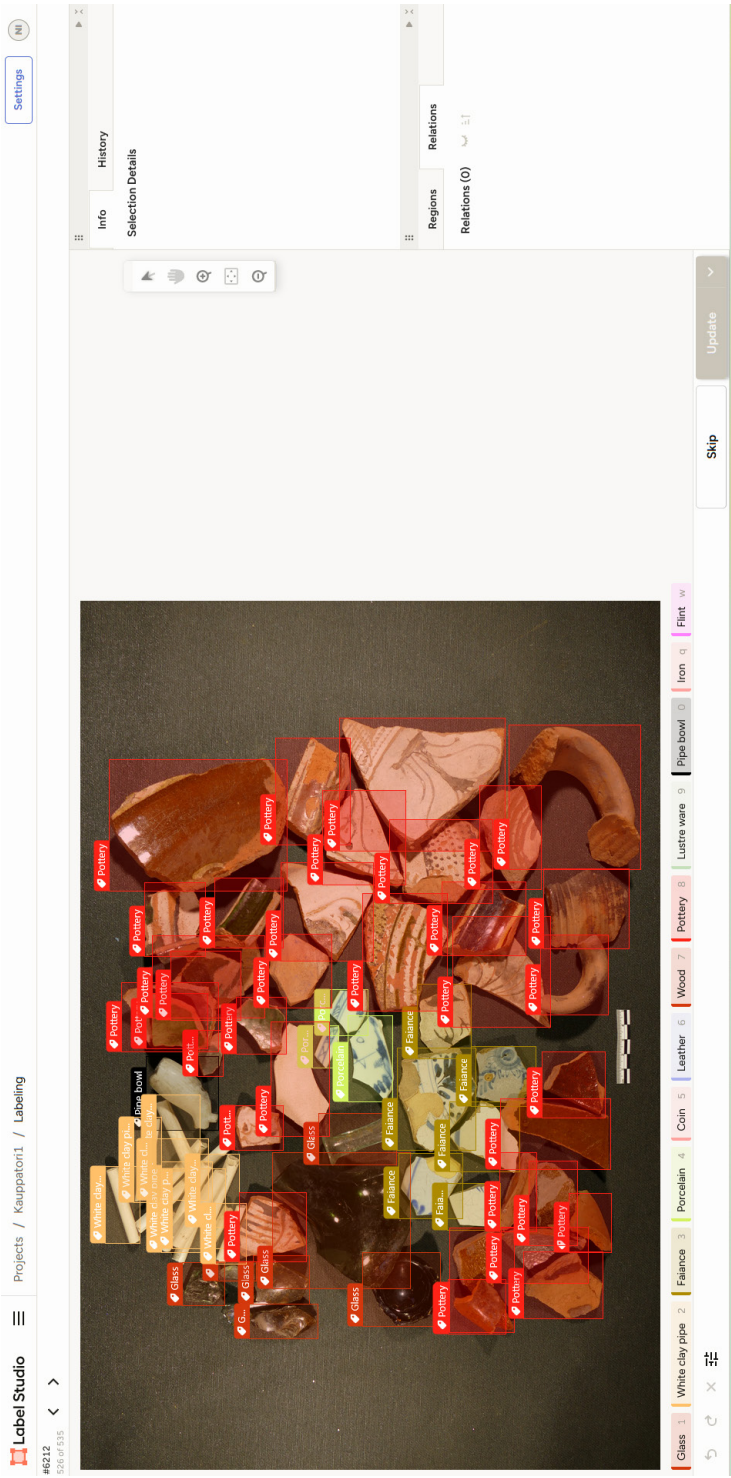

Figure 5. A screenshot from the Label Studio's graphical user interface. User can manually select bounding boxes and their classification for a series of images to be used for training.

Table 1. The find categories used for training.

Class
Coin
Faience
Flint
Glass
Iron
Leather
Pipe bowl
Porcelain
Pottery
Pipe stem
Wood

even integrating the model with a pipeline that utilizes robotics to kinetically organize and categorize finds from a conveyor belt for further confirmation of a human handler.

Description of material

Training material consisted of find images from Turku Market Square excavation, collected and photographed by Muuritutkimus Oy. The Market Square excavations in 2018–2022 were one of the largest excavation projects ever conducted in the Nordic countries, and as such, the find material is almost unique considering its diversity and size, at least in the scope of Finland (Uotila 2024).

Even though the city of Turku was founded already in the 14th century at the latest, the current Market Square area became a part of the city relatively late. Most of the finds can be dated between the 17th century and the Great Fire of Turku in 1827 (material later than this has generally not been collected) (Helamaa 2024). The somewhat brief period – only circa 200 years – guarantees that the find types remain mostly of the same general types, regardless of the actual dating. The material framework of urban life did not alter significantly through these periods: for example, the common habit of smoking manifests itself through the white clay pipe fragments, which remain visible in multiple phases of the excavation.

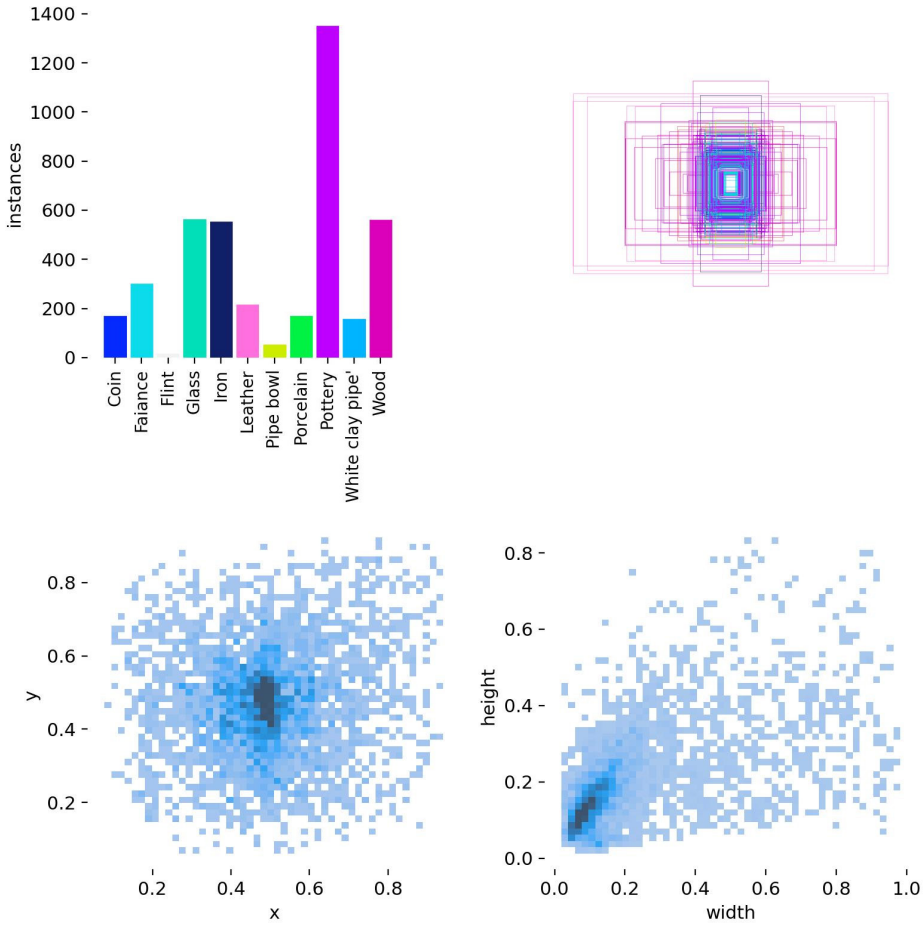

Figure 6. The output of ClearML depicting the numbers of different classes in the training material and information about the sizes and locations of bounding boxes in the images.

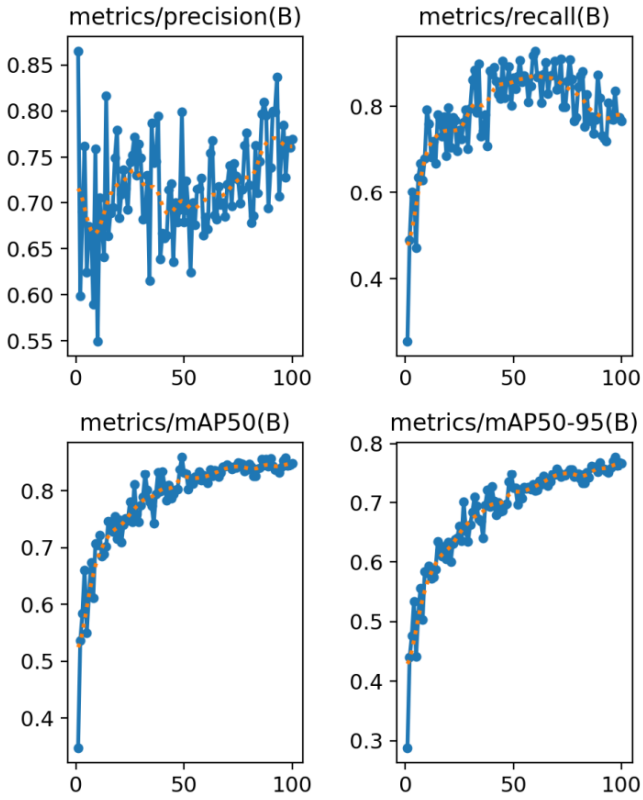

Figure 7. A summary of the results of training and validation. X-axis depicts the advancement of epochs.

Most of the photographs used for training have been taken routinely, based both on the find layers and in groups by find categories. All metal, leather and wood finds that were recovered were either conservated or removed, and were photographed before further processing. Systematical pottery photographs were taken due to research interest in the material. Many other find categories were photographed for the needs of various publications and museum exhibitions. However, of the over 183,000 recovered finds, of which over 50,000 were catalogued (Helamaa 2024), only a portion have been photographed and included in this study.

The photographs have typically been taken without a tripod, from a perpendicular angle and against a dark or black background. The usual resolution has been 5472 x 3648 or 4752 x 3168, which is suitable for this kind of shooting distances – a sufficient resolution is a requirement for a successful object detection (Nguyen et al. 2020). Overall, there were 92.3 GB or over 9000 single images available, but not all of them were used for training. The same finds had been photographed multiple times, and some of the images were too blurry, so they were left outside the training material. Additionally, in some of the pictures the identification of all objects was not possible during the annotation phase – for instance, faience and porcelain fragments can resemble each other very much, if their breaking points are not visible in the picture. This may result in errors or misidentifications when testing objects that look similar. The current annotation workflow was based solely on 2D-images, but the workflow could be altered so that the photographs would be labeled already during the photographing phase, with the archaeologist taking the photographs also identifying the objects with other methods.

It is important to note that the image material has not been initially taken with the intent of creating training datasets for machine learning. This means that there are significant discrepancies in amounts between the various

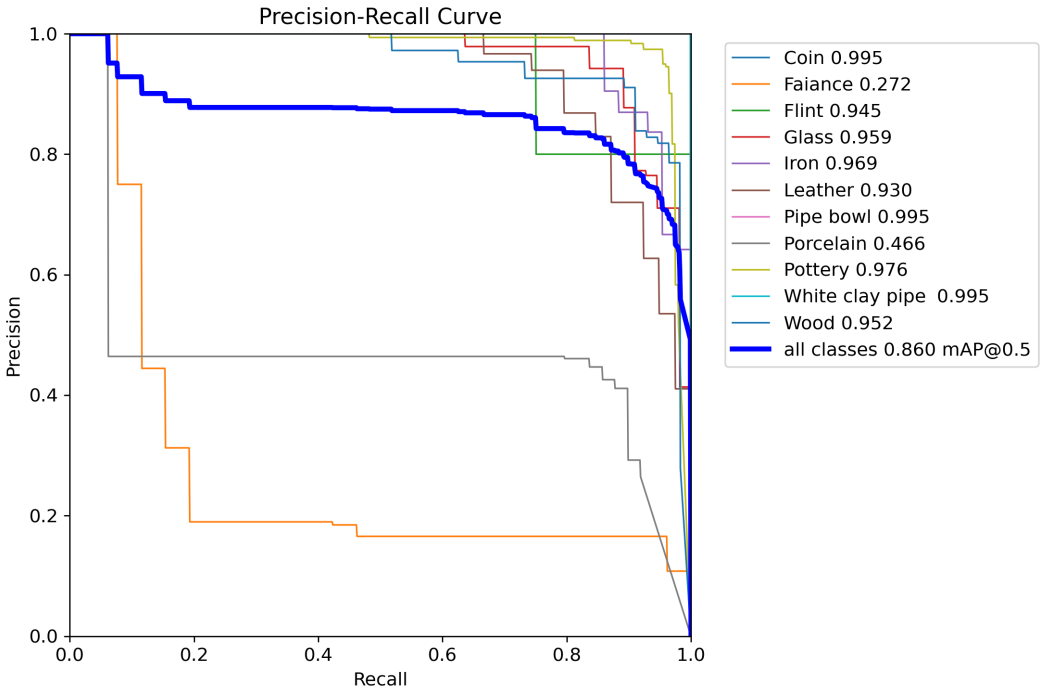

Figure 8. Precision–recall curves for each class.

find categories. This has an effect in the result of the experiment. Different find types may also have been photographed in slightly diverse ways: for example, glass and clay pipe fragments have often been photographed in large groups, whereas coins and iron objects are mostly represented by photographs of individual specimens. The material also included photographs of special finds, such as one signaling cannon, gaming pieces and a fragment of writing slate. These kinds of finds were not included in the training material.

The training material for this work included 11 classes, which represent the most common find categories in the Market Square excavation. The classes are depicted in Table 1. In addition to these categories, the excavation yielded a significant assemblage of animal bones, which had however been photographed and stored separately, and were not available for this study. The classes are mainly based on the material of the finds, so various shapes of iron, leather or wood will be collected in their corresponding groups. Coins, regardless of their material, constitute a class of their own, due to their distinct shape and archaeological significance. Various pottery types are categorized in groups of faience, porcelain, and other pottery (mostly redware). Clay pipe stummels have been categorized in a separate class due to their potential for typological dating, whereas clay pipe stem fragments have less such potential.

One of the restrictions of the training material is that almost all photographs have been taken against a single-colored dark background. This guarantees higher reliability of identification in similar conditions but might make the model less ideal in fieldwork situations or when working with photographs with light-colored or varying backgrounds. As such, more complex training material will be needed, if the model is wished to be usable in varying conditions.

Annotating, training and testing

The photographs need to be annotated before they can be utilized in training. This means that the bounding boxes and classifications

Figure 9. On the left, a series of photographs annotated manually and used for the validation. On the right the same photographs as detected by the model. The number after the class name indicates the theoretical certainty of the detection, with 0.0 being completely unlikely and 1.0 certain.

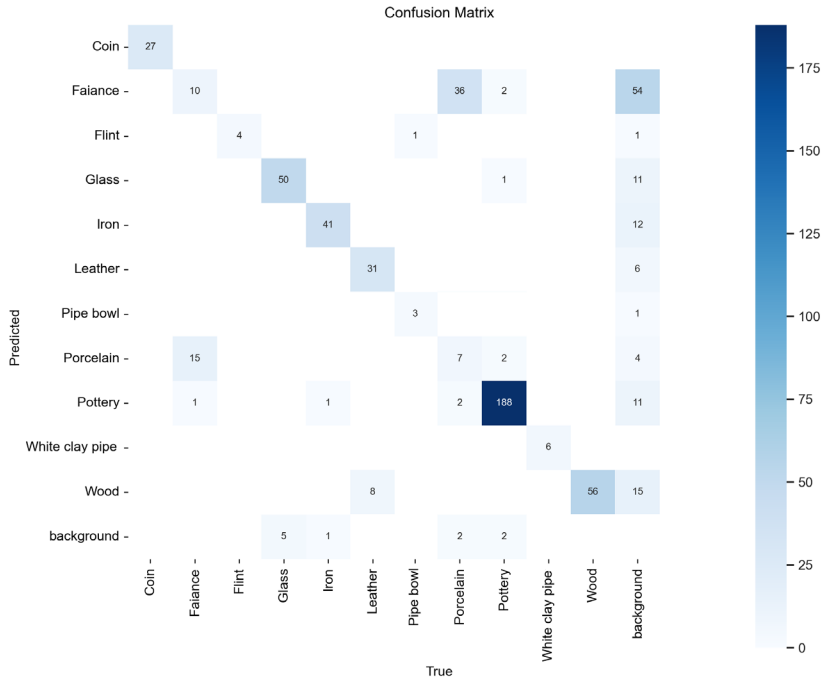

Figure 10. A confusion matrix of the validation phase which shows how all the classes are being identified. For instance, of the four pipe bowls in the training material, three are correctly identified, whereas one is misidentified as a flint.

need to be added to each individual image. For this a locally run Label Studio software was used (Tkachenko et al. 2023). In total, 1750 photographs were annotated. Most of the images had only one to five objects, but some photographs featured dozens of multiple different find types. Figure 5 depicts the intuitive user interface of Label Studio.

Annotating pictures manually is a work process that takes considerable amounts of time. Despite the straightforward user interface, the phase took almost two full working days. When a sufficient number of photographs had been annotated, they could be exported in YOLO-compatible format. Ten percent the annotated pictures were separated for automated validation, which is performed during the training to measure the efficiency of the process. This meant that the actual training process used 1575 annotated photographs, whereas the validation would use 175 photographs.

The different find types are distributed unevenly. Pottery, wood, iron objects and glass fragments featured very often in the find assemblage and were thus well represented in the training material. In turn, flint and pipe bowls were relatively few. This distortion (visible in Fig. 6) had an obvious effect on the end result of the training. The location of the objects in the image – typically in the middle of the frame – has also some effect for the applicability of the final model, i.e., it is better in detecting objects that are situated in the middle.

After the annotation and setting the dataset into a correct format, the training process with YOLOv11 is a relatively straightforward process. Since the number of training images was relatively small, it was possible to run the process in circa 20 hours on a laptop with 6GB Nvidia RTX 3060 GPU and 64GB of memory. For the study, a YOLOv11n version was executed with 100 epochs and 640-pixel image size. Monitoring and output visualization was done using open-source ClearML software (ClearML 2024).

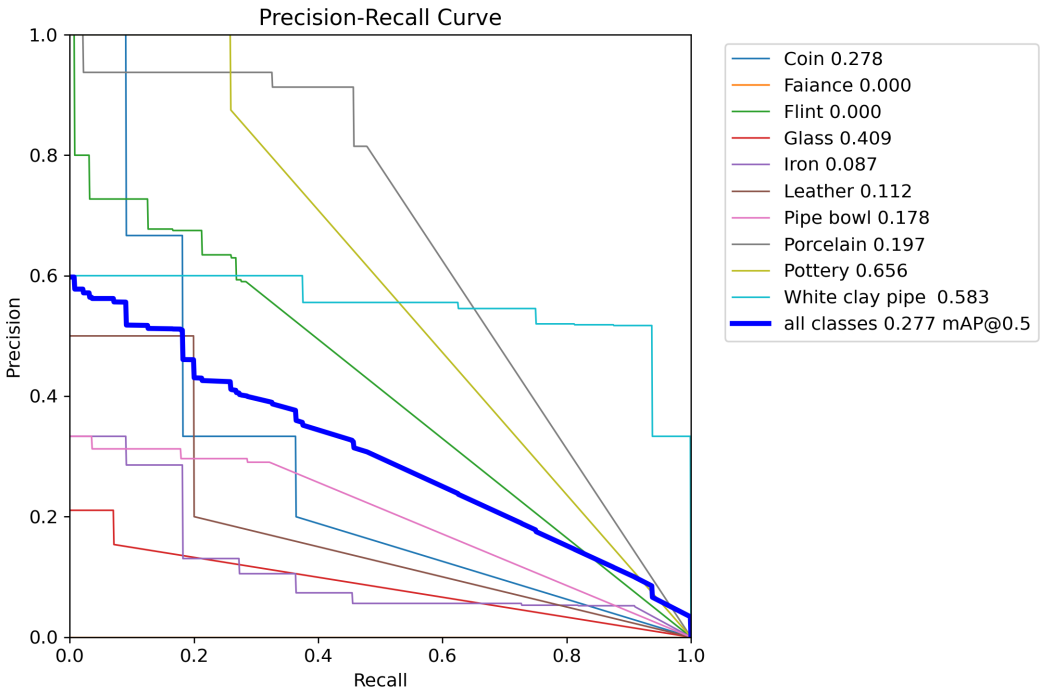

Figure 11. Precision–recall curves for each class used in testing. The results are significantly worse than during validation, and the common mAP50 value is only 0.277.

After training and validation, the model was tested with material acquired from other sources. This test material was downloaded from the Finnish Finna-service, where many Finnish archaeological projects have stored data about their fieldwork and finds, mostly in CC BY 4.0 license. The query terms used included the Finnish words referring to the find categories used for training, in addition to a general term *poistettuja löytöjä* (removed finds), since quite often these kinds of finds have been documented in mixed groups before depositing them. Quality and backgrounds of the photographs vary, but all of them represent excavation sites from the Early Modern period or later and correspond to the material that was yielded by Turku Market Square excavation. Some errors may be caused by the varying status of cleaning and preservation of the objects, since their contexts are different. Overall, 100 photographs were chosen and annotated for testing. Only by comparing the results of validation and testing phases can it be said whether the trained model could work in practice. Test results also show if the model suffers from overfitting.

RESULTS

Validation

The final results were promising in the light of the validation process. Looking at the summary generated by ClearML (Fig. 7), one can see that the mAP50 and mAP50–95 values after epoch no. 100 are above 0.8 and 0.75 respectively. However, precision–recall curve shows that the reliability of the model varies between classes, as can be seen in Figure 8. This was to be expected since the training material was biased regarding the number of representatives of different classes. For example, values for pottery or wood are quite high, whereas faience or clay pipe stummels are low. By examining how the values develop through different epochs one can also see that the precision and recall of the model has generally increased through each training cycle. Some decrease in recall in the later epochs is visible, possible implying that further training probably will not improve the results.

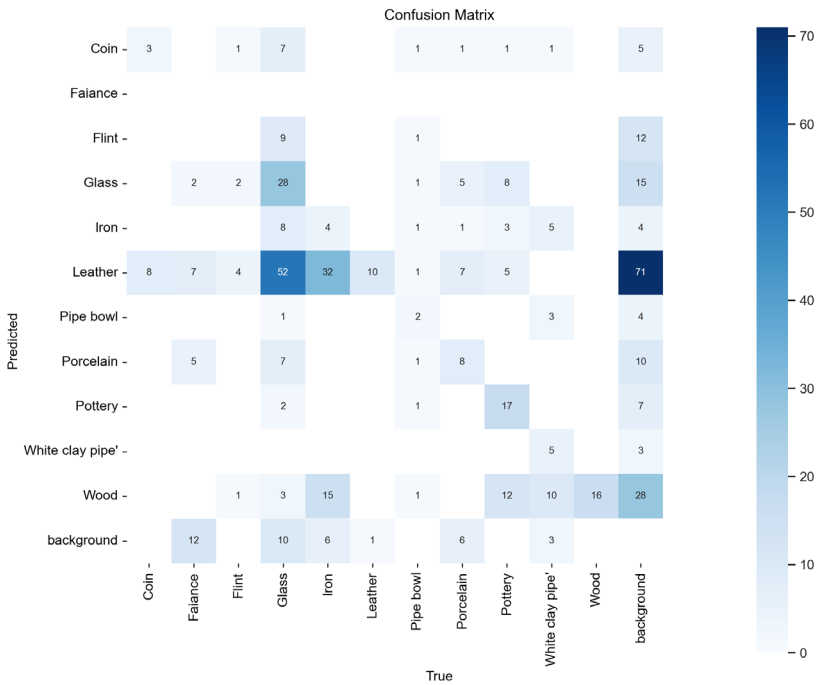

Figure 12. The confusion matrix generated on the results of the testing phase.

The results can be demonstrated by comparing the manually annotated photographs to the detections and classifications made automatically by the model during validation (Fig. 9). As can be seen, most of the classes are identified correctly, and furthermore, the model does not make detections in areas of the background that do not have any objects. However, some classes seem to get confused with each other. For example, faience, glass, pottery and flint seem to get mixed up during the validation phase, which may be related to the variably shiny surfaces of the objects (for example Chen et al. 2022).

The confusion matrix in Figure 10 further exemplifies these results. When inspecting the diagonally situated squares it is clearly visible which classes seem to be considerably reliable for detection. Coins, for instance, have almost no faulty detections. Similarly, pottery, wood, glass and iron objects yield quite good results. For other classes, the situation is slightly worse, however, and especially porcelain and faience seem to be quite often confused with each other. This is not surprising, since identifying them solely based on a photograph can be difficult even for a ceramics expert. It may be that sufficiently reliable identification based only on 2D-images is not feasible with this approach.

Based on these metrics, it seems that the quality of the model is rather promising, especially considering the most common find types. However, there is some variance between the different find groups.

Testing

After the training was finished, the model was evaluated using material acquired from other Early Modern Finnish excavation sites. This phase was crucial since it shows whether the model is actually overfitted when trying to detect objects in new contexts. As mentioned above, 100 manually annotated photographs from Finna-service were used for testing. Validation was performed using IoU value of 0.6 and confidence threshold of 0.25.

When inspecting precision–recall curves in Figure 11 one can instantly see that the results are subpar compared to the validation phase.

The confusion matrix, visible in Figure 12, shows clearly how multiple classes are mixing with each other or the empty background. There are multiple error phenomena visible which did not manifest during the validation. For instance, confusion between leather and glass is a mistake that does not happen almost at all in validation. Similarly, iron and leather seem to get mixed up due to some unknown factor. One possible factor that might cause this kind of error is the generally dark colors and angular shapes typical to both object types.

Based on the test results the model is not readily generalizable to all kinds of find assemblages of relevant periods. The dissimilarity between the results of validation and testing are likely an example of overfitting. It is likely caused by the homogenous backgrounds in the photographs of the training dataset. Especially objects on completely white background were almost always misidentified, which is understandable, since this kind of background was not present at all during training. The testing material also included photographs with red and blue backgrounds, which were similarly not included in the training data. The condition of the objects themselves had probably also an impact: for instance, the testing dataset included photographs of various heavily corroded and dirty iron objects, whereas many iron objects in the training dataset were either conservated or at least preliminarily cleaned.

CONCLUSIONS

The results of this study show that YOLOv11 could, indeed, be used for automatic detection and classification of archaeological finds. However, the presently examined results, achieved with 1575 training photographs and using YOLOv11n, are clearly not sufficient by itself, except for the limited use case of other similarly photographed Kauppatori finds. It is likely that using a larger and more varied training dataset would make the model more dependable. For example, the COCO dataset, used often for evaluating different object detection algorithms, uses 80 classes and utilizes dozens of thousands of pictures (Liu et al. 2021). Even adding a few hundred representative photographs with light colored backgrounds might help significantly. Running the training process with a heavier YOLOv11 version might also improve the

results. Additional training data could also be created using generative AI to further bolster the number of the images.

Increasing the size of the dataset is not necessarily very straightforward. Acquiring large datasets from these limited research periods requires plenty of manual work, as does their manual annotation. The easiest way forward would be to include freely licensed images from the Finna portal or the newer AADA find database, but their efficient downloading is not trivial since the portals only support downloading individual pictures. This would require a plenty of manual work.

When the reliability of the model is increased, it can also be considered for integration with actual find processing work and practical testing. By then at the latest a discussion on the ethics of the use of computer vision in archaeology must be initiated. It is important that all systems incorporating AI need to have a human-in-the-loop with archaeological expertise. Even though a single falsely identified find does not sound like a dramatic problem, it can actually lead to accumulating errors that could have a significant impact on the interpretation of the whole site. Human agents make mistakes as well, but at least in that case the questions of responsibility are evident.

The results are promising: YOLOv11 object detection model could possibly be used for automatic processing of archaeological find material when trained with a larger dataset. A project comprising of several trained annotators and access to multiple excavations' data could achieve this in relatively short time. Computer vision has been used in other archaeological applications with considerable success, and it is probably just a question of time when it becomes a common tool for find processing and research.

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Janne Ikäheimo

CONTEXTUALIZING TÖRMINKANGAS – A NEW VIKING AGE DWELLING-SITE DISCOVERED BY THE BOTHNIAN BAY

Abstract

This article contributes to our understanding of Late Iron Age settlement dynamics and socio-economic developments in northern Fennoscandia by presenting the results and broader implications of archaeological excavations at Törminkangas in Oulu, a newly discovered Iron Age dwelling site near the Kalimenjoki River in Northern Ostrobothnia, Finland. The excavations, centred around a rectangular stone sauna stove, yielded artifacts including a fragment of a bird-shaped bronze pendant and a quartzite ball, both suggestive of symbolic deposition practices. Radiocarbon dating and artifact typology place the site in the late Viking Age (ca. AD 950–1050). The study contextualizes Törminkangas within broader regional settlement patterns, paleogeographic changes, and environmental changes. The results support the existence of locally rooted communities on the Bothnian Bay coast during the Viking Age – possibly identified in historical sources as the Kvens – instead of seasonal exploitation carried out by southern migrants.

Keywords: Viking Age, Bothnian Bay, dwelling-site, sauna stove, symbolic deposition, paleogeographic reconstruction

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INTRODUCTION

The nature and character of settlement along the coast of the Bothnian Bay during the Late Iron Age, prior to the Crusade Period, has traditionally been interpreted through place names and historical sources due to the scarcity of archaeological evidence. Based on these sources, the region's Viking Age inhabitants have typically been regarded as settlers who may have arrived from the south as early as the 9th century, and who sustained themselves through a combination of hunting, fishing, and animal husbandry (Halinen 2022: 150; 2025: 281). In historical records, this group – who made versatile use of the coastal and riverine resources of the Bothnian Bay – is referred to as the Kvens (Julku 1986: 51–91). They are believed to have spoken Finnish, and based on place-name evidence, their likely place of origin has been identified as the province of Häme (Halinen 2025: 219–220; 244; 282–283; see also Raninen & Wessman 2015: 361). This population formed the foundation upon which agriculture became established in the river valleys of the Bothnian Bay, at the latest during the Medieval period. From among the Kvens also emerged the powerful peasant traders known as the Birkarls, who engaged in commerce with the Sámi and began collecting taxes from them in northern Finland from the early 13th century onwards (Halinen 2022: 150–153; 2025: 211, 282).

The absence of archaeological sources concerning the Kvens was already noted by professor Kyösti Julku of the University of Oulu in his 1986 publication Kvenland – Kainuunmaa

(Julku 1986: 136–150). However, the rise of metal detecting as a hobby in Finland since the early 2000s, has resulted in the increasing interest of professional archaeologists in new discoveries made by hobbyists (e.g., Maaranen 2016), and renewed attention to previously known stray find sites (e.g., Hakamäki 2018). This development has begun to reshape our understanding of the Iron Age in Finland – also with respect to the coastal Bothnian Bay (Kuusela 2014: 229–231). The impact has been particularly strong regarding the latest phase of the Late Iron Age, the so-called Crusade Period (AD 1050–1300). In northern Finland new coastal settlement and cemetery finds, as well as inland cremation burials with grave goods have been discovered in the regions of Lapland, Kainuu, and Northern Ostrobothnia. In the coastal Bothnian Bay, the finds dating to the Crusade Period and Early Middle Ages have notably concentrated along the lower courses of the region's major rivers (Raninen & Wessman 2015: 362). On the contrary, not much archaeological evidence of the associated settlement activity had been located and identified in the area dating prior to the Crusade Period (e.g., Kuusela 2013: 76, 117; cf. Bergman & Ramqvist 2018: 4) until recently.

In the light of this new archaeological data, an alternative explanation regarding the origins of the Late Iron Age coastal settlement in the Bothnian Bay, has been put forward. This revised perspective puts less weight on the influence and importance of southern pastoralists and agriculturalists by emphasizing the existence and the role of local, non-immigrant communities along the Bothnian Bay coast (Kuusela et al. 2016: 177–180). According to this post-colonial line of thinking, these locally rooted inhabitants are the ones referred to in early historical sources as the Kvens, and whose representatives were somewhat later known as the Birkarls (e.g., Bergman & Edlund 2016; Bergman & Ramqvist 2018: 8; Herva & Lahelma 2020: 133–135; Nurmi et al. 2020: 18–21) that acted as intermediaries by transmitting goods of Sámi inland communities to trading networks that extended far into the Central and Western Europe (Kuusela et al. 2016; 2018; Nurmi et al. 2020).

Along with the new archaeological evidence, interpretations regarding the nature of trade goods moved from 'northern wilderness' towards Europe through these networks have become more diverse, mainly due to new zooarchaeological data. In addition to traditional view underlining the importance of furs (Raninen & Wessman 2015: 292, 320, 332), recent research on animal bone assemblages has highlighted other inland products such as fish – particularly pike stockfish – as well as, somewhat later, mountain reindeer meat, antlers, and hides as important trade commodities (Kuusela et al. 2020, see also Bergman & Ramqvist 2018). Still, what has been lacking for long is the archaeological evidence concerning the Viking Age settlement and subsistence on the coastal Bothnian Bay.

Against this backdrop, a surprising but still quite predictable discovery was made in September 2022, when the first signs of a dwelling site regarding the coastal settlement on the eastern shores Bothnian Bay during the Viking Age were discovered at Törminkangas in Oulu (Fig. 1), Northern Ostrobothnia. Törminkangas is a sandy moraine ridge, located approximately ten kilometres north-northwest of the city of Oulu, on the west bank of the descending Kalimenjoki River. Today, the area is found some 4 kilometres in inland due to continuing post-glacial land uplift and is characterized by recently thinned dry coniferous pine forest, with the undergrowth dominated by various dwarf shrubs, lichens, and mosses.

The signs consisted of about a dozen metal objects found by two commendably active and exemplary metal detecting enthusiasts. These finds prompted a site visit by an archaeologist from the Northern Ostrobothnia Museum, after which a nearly one-hectare archaeological site named Törminkangas (site ID 1000049391) was delineated on a sandy plateau in the eastern part of the ridge. A significant portion of the finds recovered by metal detectorists originated from this area. The site was soon proposed as a potential location for the University of Oulu's archaeology field school in the summer of 2024. After a short but intensive phase of preliminary investigation, the decision was made to proceed with this plan.

The aim of this article is first to present the findings and observations made during the excavations, and then to set the site in its archaeological context in relation to the surrounding environment, the Kalimenjoki

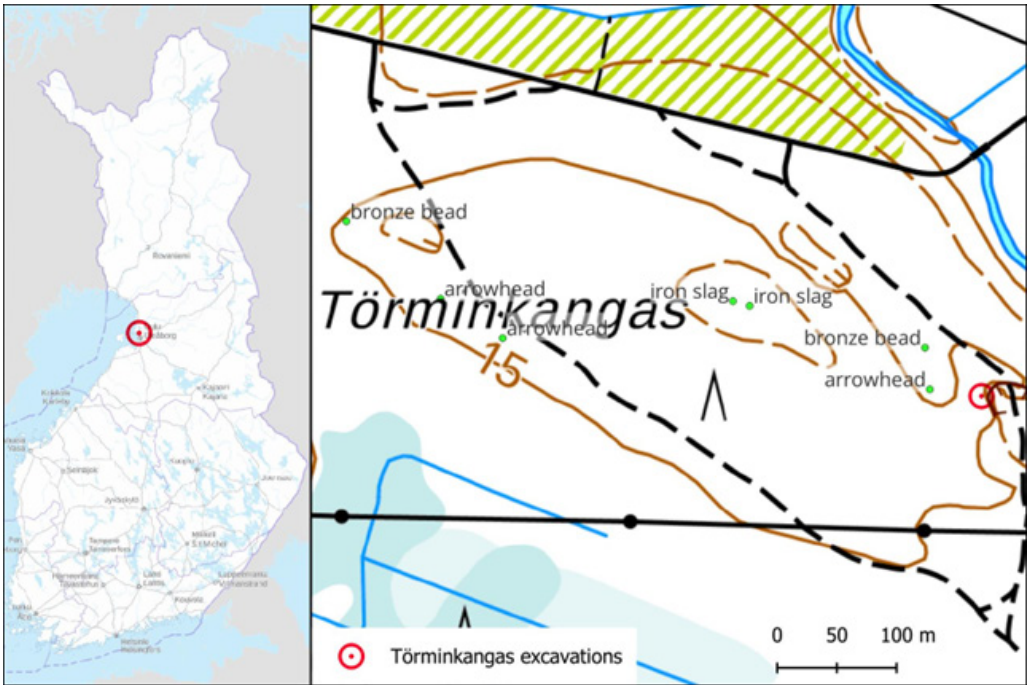

Figure 1. Location and surroundings of Törminkangas. Left: orientation map. Right: base map showing the excavation site and main metal detector finds. Base map: National Land Survey of Finland.

river basin, and the material evidence from the Bothnian Bay coast. The Törminkangas site also contributes to the ongoing reassessment of coastal-inland dynamics during the Late Iron Age. As Kuusela (2014: 235–238) has shown, a shift of activity zones from the coast to the interior after AD 600 is reflected in the archaeological record. Törminkangas, however, provides concrete evidence on the existence of coastal habitation in the Viking Age, thereby extending the known settlement chronology of the region from the Crusade Period into the first millennium AD.

EXCAVATIONS AROUND THE SAUNA STOVE

Preparations for the excavations included visits to the site with the metal detector enthusiasts who had made the initial finds. During these visits, not only the spots of the metal finds made in the area were pinpointed, but also new points where the metal detector had given promising signals were marked. These points were particularly concentrated on the western side of a modern sand extraction pit, where upon closer inspection, a small oval low mound – with an area of about 6.3 m² and a height of 25–30 cm – was observed. As the shallow mound appeared to consist of stones, it was interpreted as possible remains of a sauna stove, and its investigation was deemed as a suitable challenge for an archaeological field school.

The mound was enclosed with a 5x4 meter trench and the young spruce growing on top of the mound, presumed to be a sauna stove, was removed. Thereafter, the forest floor mat covering the mineral soil was removed, and the first stones were revealed already during this process. Some of the stones, consisting of fist-sized material, had been visibly cracked and crumbled due to heat while other stones were larger and rounder. After the removal of the topsoil and the exposure of the mineral soil surface, a circular structure with a diameter of about 2 meters emerged in the eastern quadrant of the excavation area.

Immediately upon excavating the mineral soil, charcoal, burnt sand, and relatively abundant fist-sized and smaller burnt stones began to appear. In addition to the sauna stove located

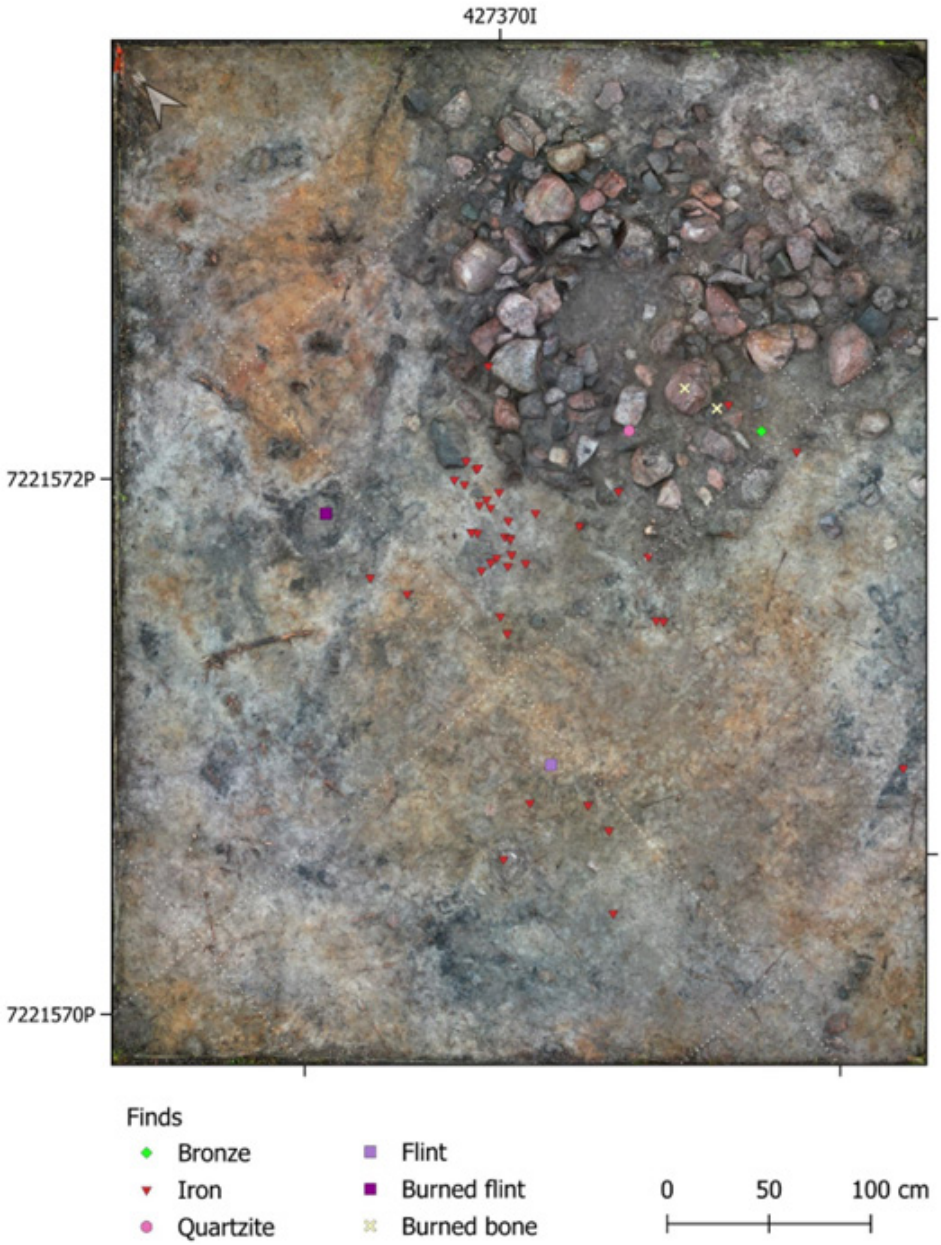

Figure 2. Orthophoto of excavation level 1, showing the sauna stove, the outline of a rectangular structure, and the distribution of finds. Photo: J. Ikäheimo.

in the eastern corner of the excavation area, other elements of interest for the interpretation of the site were to be observed (Fig. 2). A rectangular structure oriented according to the intermediate compass directions and measuring approximately 4x3 meters, outlined by narrow and elongated streaks of darker soil was observed by the stone structure. These darker streaks likely indicate the wall lines of a building or part of it. This interpretation is also reinforced

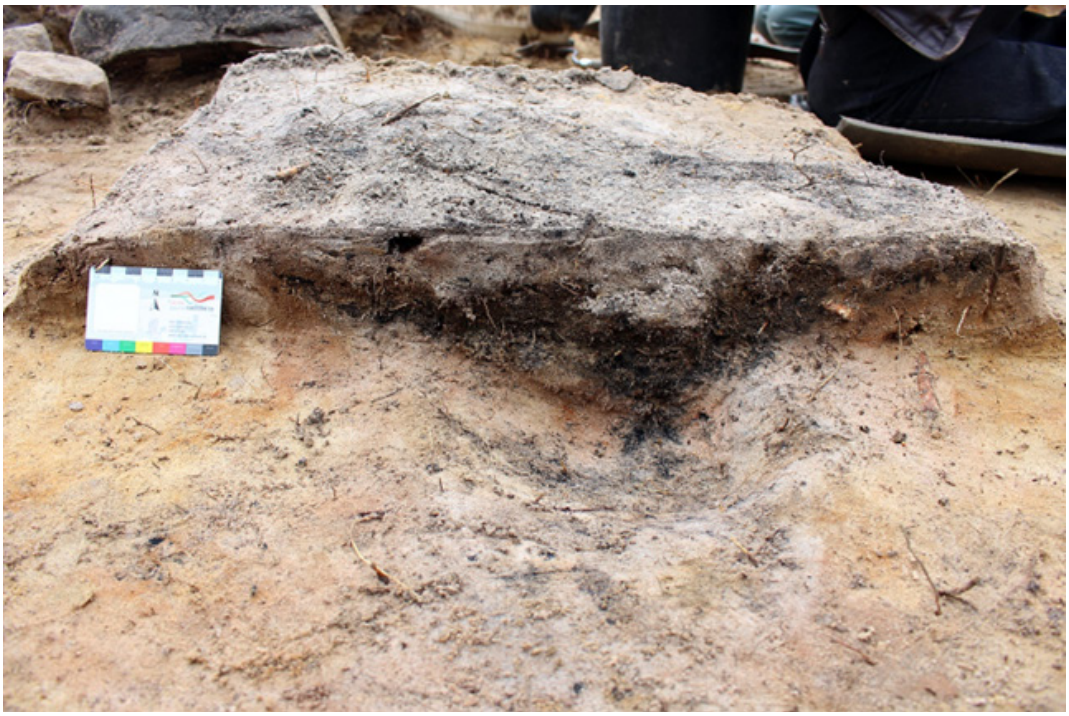

Figure 3. A possible fire conservation pit filled with charcoal and small pebbles – one of the rare features discovered at the site. Photo: J. Ikäheimo, OT-24_digi_109.

Figure 4. The rectangular base of the sauna stove with a partially excavated interior. Photo: J. Ikäheimo, OT-24_digi_164.

by the observation of a poorly distinguishable area of slightly stained soil located inside the structure, southwest of the sauna stove, which could indicate a small living space.

Another interesting area of approximately 2x0.7 meters in size was located immediately outside the northwestern wall line, near the northern corner of the excavation area. In addition to scattered stones, this area contained a significant amount of charcoal-mixed soil and burnt sand. Notably, a small and shallow pit quite irregular in overall shape and measuring about 45 x 40 cm was found at its southwestern end (Fig. 3). The pit fill consisted of charcoal-mixed soil together with stones of 2–3 cm in diameter belonging to the gravel fraction. The only find in the pit fill was a very small fragment of burnt flint (KM47021:40). The feature could be interpreted as a fire pit or a charcoal preservation pit, similarly to those previously identified at Iron Age dwelling sites in southern Finland (see Uino 1986: 190; Vuorinen 2009: 73).

As the excavation proceeded downwards, stones were removed from the sauna stove area to enable further digging. The stones in the structure fell clearly into two types: those still in their original positions and those that had shifted due to partial collapse. After clearing away the latter stones, the sauna stove itself became even more clearly defined. First, it appeared as squarish construction with approximate dimensions of 1.9x1.7 meters. However, by the time the base stones were reached, the structure had been reduced to a 1.3x1.0 meter wide (Fig. 4), practically north-south oriented – length axis direction c. 170–350° – rectangle. It is worth mentioning that the base stones had been arranged so that their top surface sloped inward. In addition, on the eastern side of the sauna stove, about 40 cm from its northern edge, a space had been deliberately left between two larger base stones. The feature was interpreted as a 'functional gap' and thought of as part of a mechanism intended to regulate the air supply to the structure.

After the removal of base stones, the soil between and below them was excavated. A three-partite zoning was observed. The northernmost zone was about 25 cm wide and consisted of grey charcoal-mixed sand, while the middle zone was about 30 cm wide and consisted of brown and dense archetypal 'cultural' soil. South of it was a similarly wide zone of yellow sand, which contained small stones. Thus, the actual fireplace of the sauna stove was first interpreted to have been in its northern part, the possible processing area south of it, while the southernmost yellow sand would have represented the grate. However, a bit later the base level of the sauna stove was noticed to slope towards the south, as the layers previously found in the northern part were revealed when digging deeper in the southern part thus nullifying the hypothesis.

Figure 5. A collection of small finds from the Törminkangas area: a) tail of a bird-shaped pendant, b) quartzite ball and c-d) bronze alloy bead found by metal detectorist. Photo: J. Ikäheimo.

FINDS AND RADIOCARBON DATING

The finds from the Törminkangas excavations (KM47021:1–42) do not provide much information about the dating of the site with one important exception. This exception is a tail fragment of a flat bronze bird pendant decorated with repoussé and punch work (KM47021:1, Fig. 5a). It was discovered in the charcoal-stained soil while the last sands of the sauna stove base were examined. The fragment is divided vertically by a three-part raised band, and towards the break surface, especially in raking light, triangular decorations can be seen. Based on its shape and decoration, the comparanda dates it most likely to the latter half of the 10th century AD.

One substantially close parallel is a swan pendant found during metal detecting at Muuntajanmäki in Valkeakoski in 2016 (KM 41815:3), which is dated in the Löytösampo service either to the Viking Age or Crusade Period. A similar pendant is included in the Viking Age chain device found at Aittokallio in Kinnula (KM 15433:4; Kivikoski 1973: 104–105, Taf. 87). Corresponding bird pendants have also been found in the graves C1 (KM 8602A:62, Cleve 1978, Pl. 1:7) and CB (KM 8602:74, Cleve 1978, Pl. 15:250) of the Lalli cemetery, or C cemetery, in Köyliösaari, Säkylä. They are dated to AD 975–1025 based on the Arabian silver coins found from the same context (Cleve 1978: 195–196).

Flat bird pendants are also known from the Baltic and Russia, where their production is associated with the cultural influence of Finno-Ugric people. In E.A. Ryabinin's classic typology, single-headed flat pendants belong to type I, dating from the 9th to the 11th century, and particularly to subtype 1 known from the Ladoga region in the 10th and 11th centuries (Ryabinin 1981: 12 table 1; see also Kuznetsova 2016: 103–109, 301, 304, 464–470). On the other hand, N.V. Khvoshchinskaya, who studied the Zalakhtov burial mound cemetery on the eastern shore of Lake Peipus, has not observed two completely identical bird pendants and thus considers the wax casting technique to be their manufacturing method. However, a bird pendant with a very similar tail was included among the grave goods of mound grave 245 of the Zalakhtov cemetery (Khvoshchinskaya 2004 tab. CV:9), which also included two Arabian dirhems dating to around the mid-10th century (Khvoshchinskaya 2004: 77 table 3).

Another interesting and somewhat exceptional find from Törminkangas is a round quartzite ball or sphere (KM47021:38, Fig. 5b) that rolled out from the western edge of the sauna stove base sand during the last moments of the excavation. The stone with a diameter of 1.4 cm, is a geofact formed by prolonged glacial river transport. However, the find was made from the charcoal layer between the base stones just above the bottom soil of the sauna stove, as if it had been deliberately placed there just like the swan pendant fragment.

Comparanda for the quartzite ball can be pointed out from the Viking Age cemetery of Hemlanden in Birka, where a similar, though slightly larger and heavier (Ø 1.7 cm; 6 g) item was found in 1881 in the burial mound no. 1069 (548555_HST). The burial likely dates to AD 800–1000 based on other artifact finds – including a Borre-style belt buckle, spearhead, arrowheads, and a knife – and the abandonment of Birka in the late 10th century AD. The stone in question is interpreted as a beach stone but has been nevertheless catalogued as a grave good (Arbman 1943: 445) indicating the apparent 'otherness' of the object in its context. Other parallels can be found in Viking Age graves in Northern Norway, where such objects have been interpreted as game pieces (e.g., Solberg 2007). However, these are made from bone, walrus tusks, horn, or hoof keratin, and instead of individual finds, the number of these objects may reach a dozen in one burial (Skomsvoll 2012: esp. 35–39, passim).

The discovery of a bird pendant tail fragment and a quartzite ball at the base of a rectangular stone oven invites multifaceted interpretation. Rather than representing accidental discard or refuse, their deliberate placement suggests intentionality rooted in symbolic practice. Viewed through different lenses, these items may have served as protective deposits meant to safeguard a structure or its inhabitants; as commemorative objects anchoring memory to place; or as elements within a ritual marking transition, whether of a person, a dwelling, or a social state. While these interpretations are not

mutually exclusive, they collectively point to the importance of meaningful deposition practices in negotiating relationships between people, objects, and place – particularly at moments of closure, change, or remembrance – in the context of fire and the hearth (see also Herva & Lahelma 2020: 166–167).

The largest category of finds – in total 50 pieces – consists of iron nails and rivets, their fragments, and pieces of iron sheet. The finds date to the pre-industrial era based on their general appearance, but giving a more precise age for conservative objects like nails or rivets is difficult. Most of the iron sheet pieces have a hole, and many of them are undoubtedly rivet washers. This interpretation is primarily based on two finds, where the rivet and its washer are still attached to each other. When examining their spatial distribution, the iron rivets and nails form a relatively dense concentration southwest of the sauna stove (Fig. 2). Therefore, they most likely belonged to the wooden support frame that held the structure together (see also Mikkanen 2016: 7).

Among the iron finds is also a piece of sheet metal about 10 x 6 cm in size, broken into nine parts but also containing two rivet holes. The pieces were found clustered about one and a half meters southwest of the concentration of iron rivets and nails, in a spot where – based on the stained soil – the end of the building can be outlined. The find could therefore be part of a latch plate belonging to the locking mechanism of a door. Hence, the entrance to the building would have been located on its southwest side. Also, iron nails found within the same area can be associated with the door structure.

One key objective of the excavations at Törminkangas was to find enough burnt bone for AMS radiocarbon dating, but burnt bones were found only sparingly in the charcoal-mixed soil under the yellow sand layer at the base of the sauna stove. These bones were found within an area about the size of a palm, and the total amount of the material collected in the field and from a sample taken from the charcoal-mixed soil was only 0.97 grams. Yet, from this small assemblage comprising 247 bone fragments, several diagnostic bone fragments of fish and birds could be identified. These include two cranial fragments of a pike (*Esox lucius*), ten fish vertebrae, and about forty other fish bones. The relatively small vertebrae resemble either pike or a whitefish (*Coregonus lavaretus*). Additionally, the material contains nine bird bone fragments and a possible mammal bone fragment.

Since the recommended sample amount for AMS-based radiocarbon dating is currently 4 grams, it was decided to preserve the aforedescribed bone material and use a sample of charcoal collected from the base of the sauna stove instead. The dated charcoal originated from a young coniferous tree, most likely a Norway spruce (*Picea abies*). The sample was AMS-dated by the Vilnius Radiocarbon Laboratory in Lithuania, with the dating result 1104±30 BP (FTMC-VV75-1). When calibrated to an accuracy of 2σ with Oxcal v. 4.4.4 (Bronk Ramsey 2021) using the IntCal20 calibration curve (Reimer et al. 2020), the result – 885 (93.0%) 997 calAD, 1005 (2.5%) 1017 calAD – places the sample to the 10th century AD, with a slight emphasis on the latter half of the century when reduced to 1σ accuracy. The result aligns well with the dating of the bird pendant tail fragment found in the sauna stove, and therefore the sauna stove with its adjacent features can be tentatively dated to the late Viking Age, around AD 950–1050.

INTERPRETING THE SITE AND ITS SURROUNDINGS

Based on the observations described above, the feature excavated at Törminkangas can be identified as a fireplace, which, due to the amount of burnt stones and the wooden support structure, is more likely to be a sauna stove than a plain hearth. The structure was not completely open from the top and side, despite the stone-free area (see Mikkanen 2016: 6), but in addition to structural stones, it also included a stone layer intended for heat retention, partially fragmented by heat. The construction on the ground surface and the location in the corner of a room are also characteristic features of a smoke sauna stove (Mikkanen 2016: 9–10; see also Vuorinen 2009: 60–61). On the other hand, due to sparseness of finds, and proximity to a small river (e.g., Halinen 2016; 2025: 226–230), the site can be paragoned to the hearth-stone dwelling sites of Sámi hunter-gatherers.

The excavations provided only indicative information about the nature of the room or building surrounding the sauna stove, in the form of weak dirty soil marks in the ground that possibly indicated wall lines (cf. Vuorinen 2009: 60–61). The wooden building was thus founded in the typical manner of the era directly on the ground surface following the eastern building tradition (e.g., Viitanen 1996: 9). The building was likely a single-room cabin, which could also have doubled as a sauna and drying barn. In this respect, a detail worth noting is the very small amount of burnt bone found in the sauna stove. It may be explained either by the function of the building or by the fact that food preparation took normally place elsewhere, such as in a cooking hut belonging to the yard. A somewhat later example of a cooking hut latter can be pointed out from Ii Pirttitörmä, a 13th–14th century AD dwelling-site on the Illinsaari island located just 20 kilometers north of Törminkangas (Hakamäki & Ikäheimo 2015: 17–18), where a lighter stone structure used as a fireplace was discovered in the proximity of a sauna stove. Alternatively, charred bones might have been frequently raked out with ashes and disposed elsewhere, while the maximum temperature in the combustion chamber may have been sufficient to disintegrate most of the bones.

In a slightly broader perspective, the mound observed during the preparation stage of the excavations presents a source-critical problem as it became the focal point of the investigations (Mikkanen 2016: 6), which in turn cannot help but affect the overall interpretation of the site. Nevertheless, based on the artifact finds, the excavated structure, the phenomena observed in the soil, and the radiocarbon dating, Törminkangas can be interpreted as an Iron Age, primarily Viking Age dwelling site.

This is also indicated by the traces of another sauna stove observed during the investigations on the edge of the sand extraction pit located southeast of the excavation area. Burnt stones and one larger structural stone had been pushed to the edge of the pit during the mechanical removal of the topsoil from the nearby area. Most of these stones were found on top of the original ground surface mixed with sand, while some were found in the collapsed section of the pit. When surveying the surroundings with a metal probe, no stones were felt below the original ground surface, yet the evidence clearly points towards to the existence of another sauna stove structure nearby.

The activities related to site are not limited to the eastern edge of the ridge, as the spatial distribution of finds made by metal detectorists while sweeping through the Törminkangas area is much more extensive (Fig. 1). The finds relevant to the interpretation of Viking Age activities both in the vicinity and to some distance of the site consists of three iron arrowheads, two bronze-alloy beads and several fragments of iron slag. Some of these finds (KM 46856:1–6) – an arrowhead and a bronze bead – pertain to the same sandy plateau on the eastern edge of the ridge where the excavations took place and their spatial distribution together with additional detector signals left unearthed bear witness to the extent of the dwelling-site itself.

Figure 6. All arrowheads found in the Törminkangas area date to the Late Iron age, despite differences in their typology. Photo: J. Ikäheimo..

The same interpretation does not necessarily apply to the pieces of iron slag and fragmentary iron objects (KM 46856:1–4) found in the central part of the ridge, near its highest point and about 220 meters northwest of the epicentre of archaeological investigations. This find location named Törminkankaan laki (site ID 1000051560) might not only represent backscatter from the coeval habitation nearby or indicate the presence of a smithy, as the presence of slag is a well-documented feature in Late Iron Age burial grounds (e.g. Sheperd 1997; Wessman 2010: 90–91) in Finland. In addition, the location near the hilltop would be quite typical for a so-called cremation cemetery under level ground (Wessman 2010: 21), but as the distribution of this type of cemetery is limited to the southern part of the country, further archaeological fieldwork is obviously needed to clarify the context of these finds. Still further away, in the western part of the ridge, about 550 meters northwest of the excavation site, additional two arrowheads and a bronze bead (KM 46805:1–3) have been discovered without an apparent context – hence they constitute together find location Törminkangas 2 (site ID 1000051476).

While the three tanged arrowheads found at Törminkangas are typologically different from one another (Fig. 6) – comprising a

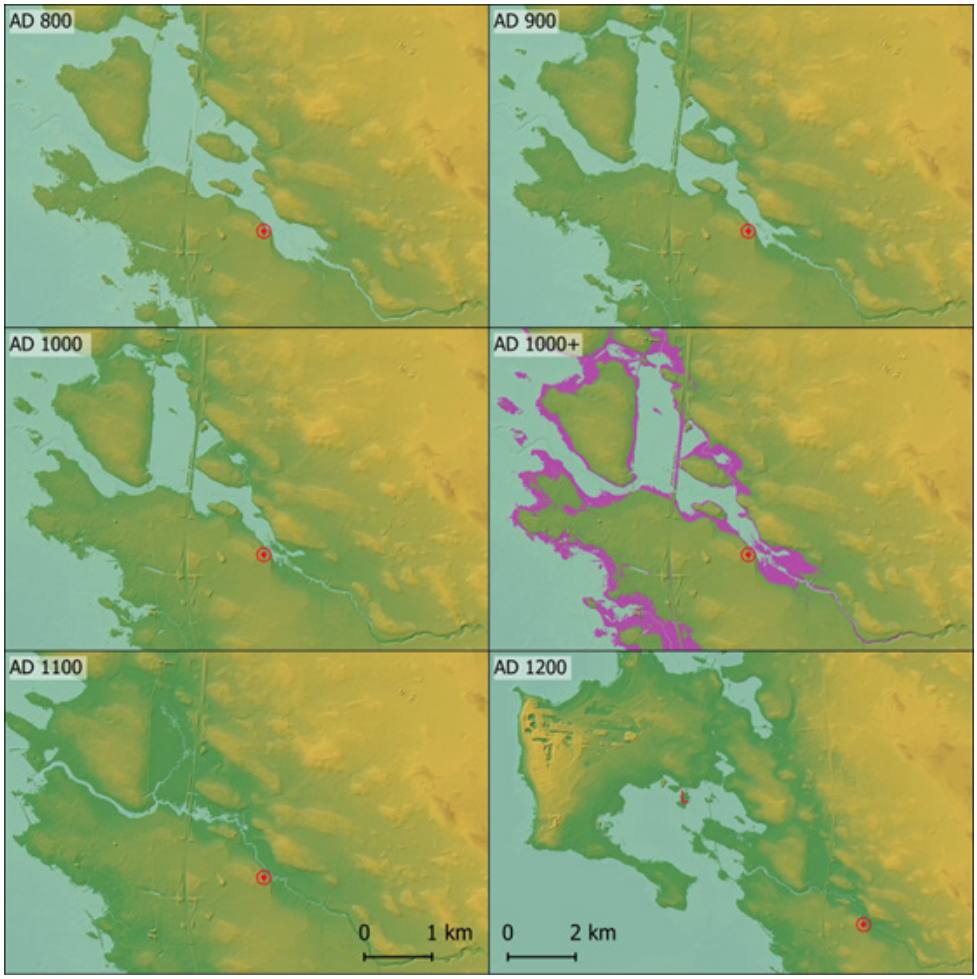

Figure 7. Paleogeographic land-uplift reconstructions done with GLARE-model (Hakonen 2024; 2025) showing shoreline development of from AD 800 to AD 1200. The Lopakka site is marked with a red "L" in the AD 1200 reconstruction. Drawing: J. Ikäheimo, elevation data: National Land Survey of Finland.

chisel-ended, a flattened, semi-circular and a leaf-shaped hunting head – they all date to the Late Iron Age (see Hiekkanen 1979). As all arrowheads are quite heavy (16.1–27.5 g) and long (110–173 mm), they were most likely used with self-trigged bows for passive hunting of large game (Joona & Kotivuori 2011: 13; for the method, see Huggert 2002) like elk and deer. This observation is an important addition to the results of zoo-osteoarchaeological analysis, which hinted to the importance of fishing and fowling as sources of local livelihood.

The two bronze beads found in the area are also very different in terms of typology. The smaller bead, KM48920:1 (Fig. 5c, 2.39 g), which is a tubular bead, has a short barrel-shaped body with evenly thick, spiral-decorated ends on both sides. In appearance and dimensions, it closely resembles a bead from a necklace (KM1400:391) purchased by J.R. Aspelin in 1872 or 1877 from villagers in Ananjino, Vyatka Province, Russia. The larger and heavier bead, KM46805:1 (Fig. 5d, 8.51 g), has a flat top and semicircular side profile. Due to its rather generic shape, no actual parallels can be pointed out. It is also worth noting that the hole of the bead was filled with charcoal or ash when found, which may provide clues about the processes that led to its deposition.

THE SITE IN WIDER CONTEXT

A wider perspective is also needed here to contextualize the Törminkangas dwelling site with the topography and archaeology of the surrounding area. It is appropriate to start the discussion by paying attention to post-glacial land uplift in Fennoscandia based on GNSS satellite positioning, for which uplift values were published under the acronym NKG2016LU by the Nordic Geodetic Commission (Vestøl et al. 2019). Calculated from the current land uplift rate of 8.16 mm per annum, the plateau east of the Törminkangas ridge, located at an approximate elevation of 15 m above sea level, arose from the sea around AD 100. This is, of course, only a tentative *terminus post quem* for the earliest possible human activity on the ridge,

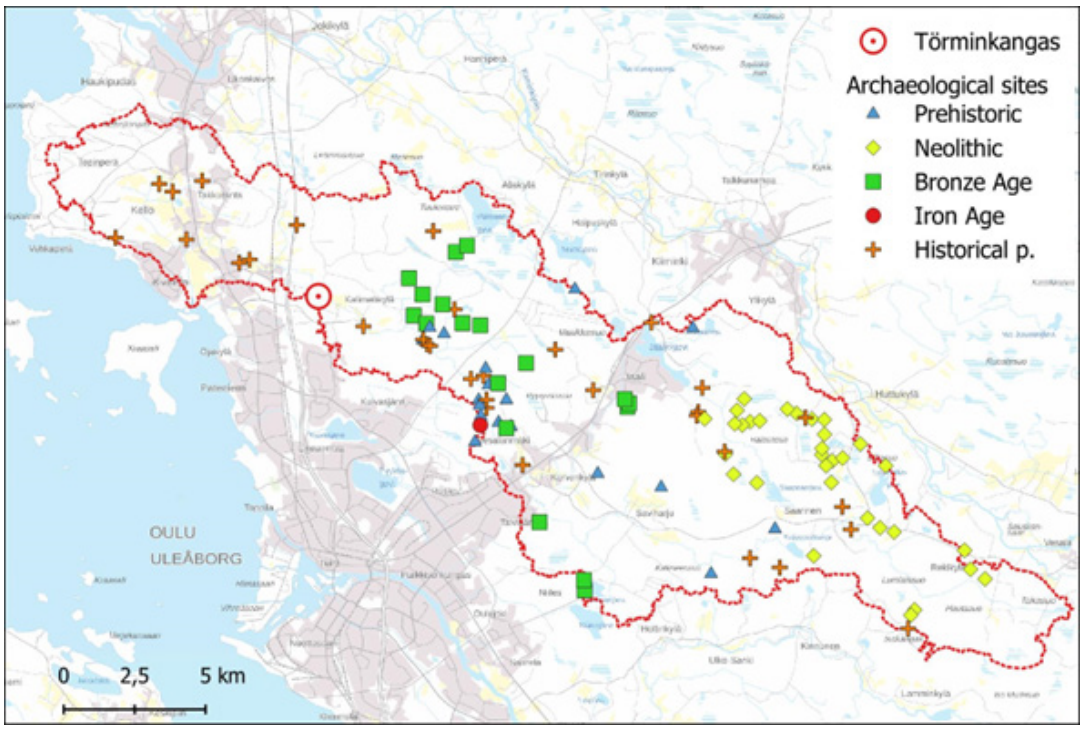

Figure 8. Distribution of ancient sites in the Kalimenjoki watershed is weighted towards Neolithic and historical dwelling-sites as well as Bronze Age or pre-Roman Iron Age cooking pits. Drawing: J. Ikäheimo, site data: Finnish Heritage Agency.

and in practice, attention should be directed to the late Iron Age periods.

The GLARE-model is an application developed by Aki Hakonen (2024; 2025) that utilizes NGK2016LU data to produce accurate sea-level reconstructions in the past, for example, regarding Törminkangas' position relative to sea level at a specific moment. If we begin the examination from AD 800 (Fig. 7), Törminkangas is located on a peninsula protruding into the sea south to the estuary of the Kalimenjoki River. A large bay is seen east to the site and although it is protected by the island of Palonkangas, the estuary is relatively open to the sea. The mouth of the Kalimenjoki River is located just few hundred meters east of Törminkangas.

With respect to local topography, the time around AD 900 represents the beginning of the optimal phase of the dwelling site's use, which continues until the first decades of following next millennium, thus corresponding well with the results of ^{14}C-dating. During the following century, the mouth of the Kalimenjoki River shifted only about a hundred meters further northeast due to the Medieval Warm Period which caused the upheaval of the sea level by about 60 cm and compensated for a significant part of the land uplift's impact on the landscape. Therefore, in AD 1000, the Kalimenjoki river mouth was practically in front of Törminkangas.

Considering the annual sea level variation in the Gulf of Bothnia, which is on average about ±1.4 meters at the latitude of Oulu (Fig. 7, AD 1000+), the large flood or coastal meadow east of Törminkangas around AD 1000 with its elevated biomass production might be the most significant factor explaining the location of the site. The low meadow was very likely the source of fish and bird bones detected in the somewhat limited osteological assemblage of the excavations. Moreover, the name of the Kalimenjoki River itself hints to the importance of fish. In its name the Finnish suffix for a river, *-joki*, is in this case paired with the prefix *Kalimen-*, a plural for the word *kalin* signifying a (part of a) dragnet in Fenno-Ugrian languages (SES 2025: sv. *kalin*). Pike as a lean fish could be easily dried and preserved for the winter (Halinen 2025: 266), and from historical records we also learn that pike stockfish was not only an important item of export for local inhabitants during later times (Halinen 2025: 281), but also an item used to pay taxes in kind (Asunmaa et al. 2015: 22, 28).

By the year AD 1100 the environment around Törminkangas had changed significantly. Now, the site was clearly located inland, although still close to the Kalimenjoki River, as the land-uplift had migrated the river mouth about 3.7 km to northwest of Törminkangas. A century later, AD 1200, a new and even more sheltered bay was forming in this area, around which the historical village of Kello with its long-lost 15th century chapel was later clustered. Therefore, based on topography and elevation, the most likely dating for the site is AD 900–1000, which aligns well with both the artifact finds and the chronological information provided by radiocarbon dating.

The Viking Age dwelling-site of Törminkangas can also be examined against the current knowledge about the archaeology of the Kalimenjoki River watershed from which altogether 114 ancient sites are known today (Fig. 8). About a quarter of them are Stone Age dwelling sites located in the eastern part of the watershed close to the Kiiminkijoki River – most of these sites include Neolithic pit houses. The continuity of human presence is indicated in Kalimenkylä and Jääli by cooking pit sites dating most likely to the late Bronze Age or pre-Roman Iron Age. However, no other proper Iron Age sites than Törminkangas are known from the Kalimenjoki watershed.

For the evidence of settlement continuity after Törminkangas one must consider those ten sites classified as historical house or cottage foundations or village sites in the Ancient Relics Register (Muinaisjäännösrekisteri) maintained by the Finnish Heritage Agency. In this context the most significant of them is the village of Kello located about 7 kilometres northwest of Törminkangas. Kello was among the first hubs established by agriculturalists from southern Finland on the eastern coast of the Bothnian Bay during the early Medieval period (Asunmaa et al. 2015: 20). Of particular importance there is the Lopakka site found and excavated between 1990–1991 on the eastern edge of Satalahdenmäki Hill (Fig. 7, AD 1200).

Similarly to Törminkangas, the remains discovered at the Lopakka site were interpreted

as a house, approximately 6x6 meters in size and equipped with a sauna stove (see Koivunen & Sarkkinen 1994). The dating of the site to the turn of the 13th–14th centuries is based on found artifacts (approximately AD 1000–1300) and on local land uplift rate. Today, the site is located approximately 7.4 meters above sea level, the current land uplift rate in the area is 8.353 mm per annum, and the annual variation from the mean sea level in c. ±1.4 m. By applying Okko's (1967: 15) equation to these figures but using 6.00 m a.s.l. as *altitudo post quam*, the earliest possible date for the construction of the house can be estimated as AD 1195.

This result leaves a chronological gap of about two hundred years between the buildings of Törminkangas and Lopakka. It is more likely the outcome of the current state of research rather than an actual gap in the succession of local settlement sites. While the mouth of the Kalimenjoki River migrated westward over the centuries due to land uplift, new sheltered bays and coves with coastal meadows were formed in front of them. With their abundant resources, including not only fish and aquatic birds but also the hay needed for animal fodder, local people could supplement their livelihood.

SUMMARY & CONCLUSIONS

The excavations of Törminkangas in Oulu focused on investigating a low stone mound tentatively identified as a sauna stove. The observations made and the artifacts found during the 2024 excavations corroborated this interpretation – the structure is a rectangular sauna stove, approximately 1.3x1.0 meters in size, built with large stones and likely supported by a wooden frame of logs or planks. The building associated with it was most likely a small log cabin with an earthen floor (see Vuorinen 2009: 27) – a dwelling, sauna, or drying barn, or a combination of these.

The structure and possibly also the site dates to the final decades of the Viking Age, either to the late 10th century AD or to the early 11th century AD. This date is corroborated with the artifact finds, radiocarbon dating of the charcoal from the stove base, and the topographic reconstruction of the area. Observations from the immediate and somewhat more surroundings of the excavations suggest that Late Iron Age settlement and other activities at Törminkangas were significantly more extensive than the site reported here. The site is quite rare in type and chronological position relative to the ancient relics of its surrounding area and even its province. Therefore, special attention should be paid by local authorities responsible for the protection of archaeological cultural heritage to preserving the Törminkangas area from modern land use.

Törminkangas also stands out from other Late Iron Age dwelling sites on the eastern coast of the Bothnian Bay due to two characteristics. First, it is clearly earlier than the other dwelling-sites and predates in chronology also the dated cremation burials known from the region (e.g., Kuusela et al. 2016: 184–186 table 1; 187 table 12). Second, the Kalimenjoki River, near which Törminkangas is located, is only 35 kilometers long, and its drainage basin covers merely 224 km². It is thus a medium-sized river, whereas the lengths of the Siikajoki, Iijoki, Oulujoki, and Kemijoki Rivers are measured in hundreds of kilometres, and their drainage basins span thousands of square kilometres. Therefore, the Kalimenjoki River did not function as a route to distant and unfamiliar places (cf. e.g., Bergman & Edlund 2016; Herva & Lahelma 2020: 124, 127), and thus its mouth did not carry the same significance as that of the major rivers of Ostrobothnia and coastal Lapland.

Nevertheless, Törminkangas exhibits many features that are comparable to those of later and more strategically central sites. For example, the site's material culture consists of elements originating from various directions (see Kuusela et al. 2018: 771–773): the building and the other bronze bead are of eastern type, a fragment of a bird-shaped pendant points to Southern Finland, Russia, or the Baltics, while the best comparanda for the quartzite ball found in the west. Thus, the site may represent an early stage of a development that became more pronounced during the Crusade Period and the early Middle Ages, when the original local communities – possibly known in historical sources as the Kvens or the Birkarls – along the coast assumed roles of control and intermediary status between inland producers and actors arriving by sea from the south, who were connected to Viking trade networks.

To conclude, the nature of the Törminkangas site suggests a more extensive and structured

settlement than initially as anticipated. The distribution of finds across the ridge, including iron arrowheads, bronze beads, and slag fragments, indicates that activity was not limited to the area surrounding the excavated sauna stove. Moreover, indirect evidence from the sand extraction pit points to the existence of another stove structure, possibly associated with a separate building. If the building containing the stove is interpreted as a sign of permanent habitation, it supports the view that the Kvens did not merely exploit the Bothnian bay region seasonally or from afar. Instead, they likely formed locally rooted communities along the coast, as recent research suggests. This interpretation aligns with the broader reassessment of Iron Age settlement dynamics in northern Fennoscandia, emphasizing indigenous agency and continuity alongside colonization from the south.

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Karen Niskanen & Aki Hakonen

LACUSTRINE LANDSCAPES OF THE RED-OCHRE CLIFF PAINTINGS IN FINLAND – NAVIGATING CHANGE

Abstract

The majority of prehistoric red ochre pictographs in Finland are cliff paintings located in the inland Lakeland region. Throughout millennia, shoreline changes have affected lacustrine landscapes and water routes. The main cause is the uneven rate of post-glacial land uplift, which causes land to tilt over time. This tilt has resulted in both gradual and rapid geographic changes. Tracking these changes may unveil how the people themselves regarded this temperamental landscape. We examine the pictographs as mnemonic landmarks along ancient waterways of Lakes Päijänne and Saimaa. The analysis applies a new land uplift model to track shifting shorelines and their impact on rock art tradition. Digital terrain models are processed to examine the shifting of water routes, and to re-examine submerged and exposed phases of pictograph sites. The paper posits that with pictographs people may have established the locales as powerful places that agglomerated varied human and non-human agencies from within the hunter-gatherer cosmos, reflecting the perceived instability of the landscape itself.

Keywords: Rock art, Neolithic, Finland, land uplift, geomyth, GLARE

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INTRODUCTION

In Finland, there are approximately 120 prehistoric rock art sites (Fig. 1), the majority of which are found on cliffs in the Lakeland region (Fig. 2). The earliest pictographs in Finland are currently dated to the Early Neolithic (5200–4000 BCE), with their painting presumed to have ended around or after 2000 BCE (e.g., Jussila 1999: 132; Seitsonen 2005; Lahelma 2008a: 41; Mantere 2023b: 165–166). The pictographs are often considered insightful yet enigmatic, their absolute meanings lost in time. Still, many fragmentary elements of the prehistoric world, even deep into the metaphysical, can be postulated and examined through rock art (e.g., Lahelma 2007; 2008a; 2019; Herva & Lahelma 2020; Mantere 2014; 2023a; 2023b).

This article focuses on the roles of water and animate land in the context of the two largest prehistoric cliff painting sites (Fig. 3): Saraakallio (in Lake Päijänne), which has 60 images; and Astuvansalmi (in Lake Yövesi, part of Saimaa), which has between 60-80 images, according to Lahelma (2008b). This paper explores the role of these two sites

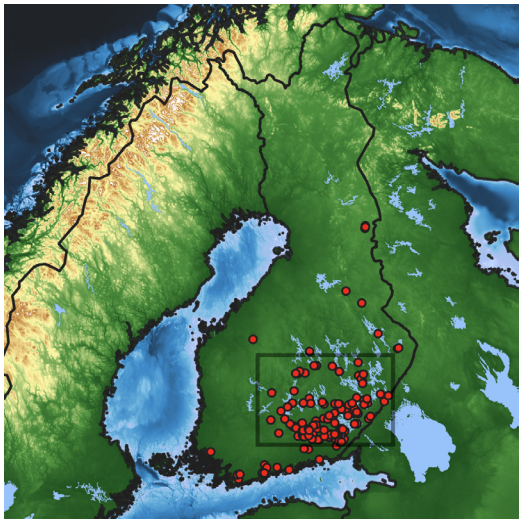

Figure 1. Rock art sites in Finland, rectangle shows the extent of Fig 2. Background GEBCO 2024 Grid (CC BY 4.0). Image: A. Hakonen.

as cultural and navigational landmarks in a changing landscape. The point of departure here is the hypothesis that the rock art sites in Finland's Lakeland region provide evidence of how people navigated and interacted with their environment (see also Gjerde 2010: 406–16). To access these issues, this research applies the new Post-Glacial Land Adjustment Regenerator (GLARE) model (Hakonen 2025a; 2025b). The model establishes a holistic approach to lake tilt modelling by applying the latest elevation data and glacial reconstructions from across Northern Europe to reshape current digital terrain models (DTMs) into simulations of past landscapes. New lake reconstructions are generated from the elevation contours of the simulated landscapes.

The process of post-glacial land uplift has caused significant changes in the vertical positioning of all prehistoric sites over time, and rock art sites are no exception. By extrapolating the regionally varying rates of

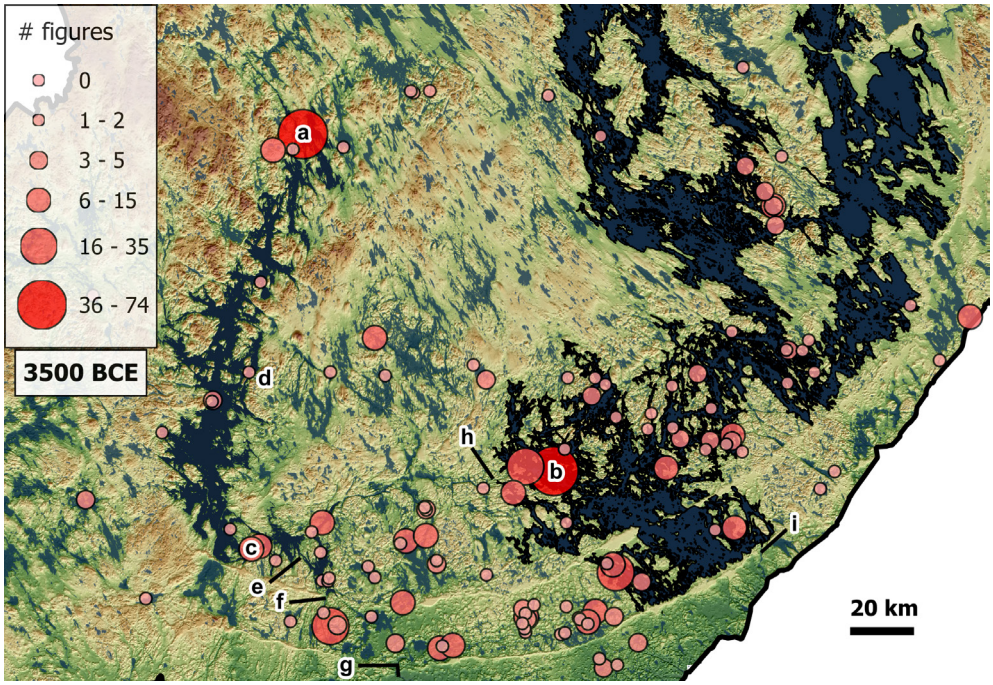

Figure 2. Rock art sites in the Finnish Lakeland. Topography and lakes at around 3500 BCE. Figure count 0 means the site contains only smudged and unrecognisable red ochre figures. Lettering shows locations mentioned in the paper: a. Saraakallio; b. Astuvansalmi; c. Patalahti; d. Avosaari; e. Heinolanharju Ridge; f. Vuolenkoski; g. Kymijoki River; h. Pieni-Varpanen; i. Vuoksi River. DTM modified from National Land Survey of Finland (NLSF) 10 m resolution elevation model (CC BY 4.0). Image: K. Niskanen & A. Hakonen.

Figure 3. The cliffs of Saraakallio (a and b) and Astuvansalmi (c and d). Photos a and d by Pekka Kivikäs and the Museum of Central Finland (CC BY-ND 4.0) b and c by Ismo Luukkonen (published with permission). Modified by Aki Hakonen.

uplift back in time, we can estimate the timing and scale of these shifts. The uneven rate of uplift causes land tilting, which in turn causes so-called lake tilting, where shorelines may have transgressed and regressed on different parts of the same water system. This effect is well known in the context of the pictograph sites of the Finnish Lakeland (e.g., Matiskainen 1979; Jussila 1994; 1996; 1999; Seitsonen 2005, 2008; Hakulinen 2011). Here, we attempt to further study and update the timing of the submerged and exposed phases of the sites, thereby illustrating how environmental changes and human agency acted together in the context of rock art.

The rate of land uplift was regionally uneven and initially faster, decelerating over time. Land uplift was stronger in the northwest and weaker in the southeast, which forced lakes to tilt. This phenomenon caused three major lacustrine shifts that are relevant here: Great Lake Päijänne, which had previously discharged via its northern channel to the Gulf of Bothnia in the northwest (e.g., Aario & Castrén 1969; Siiriäinen 1970; Saarnisto 1971), changed its outflow to the southeast (e.g., Taavitsainen et al. 2004) around 5400 BCE when the high waters burst through the Heinolanharju Ridge (Hakulinen 2025) and formed the Kymijoki River as the new outflow. Some centuries after this the Great Lake Saimaa, which for millennia flowed into the Greater Lake Päijänne via a northwestern channel, redirected its outflow to the southwest, streaming out through small channels into the new Kymijoki River and the Gulf of Finland, bypassing Lake Päijänne completely (e.g., Tikkanen 2002). A third major event occurred around 4000 BCE (possibly 3900 BCE as per Oinonen et al. 2014; cf. Mökkönen & Nordqvist 2014) as Lake Saimaa burst through the Salpausselkä end moraine, lowering the lake level by 2 metres and rerouting the flow from the Kymijoki River channel towards Lake Ladoga in the south-southeast and settling

as the Vuoksi River (e.g., Saarnisto 1970; Hakulinen 2011; Mökkönen 2011; Mökkönen & Nordqvist 2014; Oinonen et al. 2014).

Such events can be rapid. But even the slower lake tilt process would have eventually been noticed by those living along the water. Not only would oral tradition record the observed changes, but so would the rock art, where, indeed, the older paintings intuitively seem to have been created when the lake levels were higher, and as the lakes lowered new paintings were created below (e.g., Seitsonen 2005). Therefore, the landscape was an active agent influencing human behaviour, while people, through the creation of rock art, actively—intentionally or not—marked, recorded and memorialised their changing world. At Astuvansalmi, the result is a film strip of vertically sequential paintings in bands or horizons (see e.g., Seitsonen 2005: 11). However, the communities in the Lakeland were not alone in needing to adapt to a changing environment. In Denmark, for example, where floods transformed the Early Holocene landscape, "the hunter-gatherers [sic] most important faculties were the ability to exploit and maintain cultural as well as social contacts [...]. But the changed landscape [...] also changed the way hunter-gatherers interacted and communicated" (Sørensen & Casati 2015: 62). One way to access the effects of these kinds of changes is through spatial analysis that allows us to reconstruct the palaeotopography and to visualise the landscape as it used to be (e.g., Delannoy et al. 2024). To this end we investigate the changes in the landscapes around two major rock art sites and interpret the effects of these changes to the collective memory and worldviews of the locals.

METHODOLOGY

Landscape simulation

The study applies a new land uplift model that was originally developed for the purposes of this paper, Post-Glacial Land Adjustment Regenerator (version 2.2) or GLARE (Hakonen 2025b). The model is based on a relatively simple two-part mathematical Maxwell model, which simulates the rebound of depressed elastic material, with an added sea-level variable, which can be used to recalculate Digital Terrain Model (DTM) elevation values cell-by-cell. Alongside a general sea-level variable, the model applies three regional variables: 1. current uplift rate, 2. year of final glacial melt, and 3. maximum thickness of the last ice sheet. The first variable is applied in the model's slow component, based on Okko (1967), which accounts for the slowly decelerating land uplift in effect today, based on the official land uplift model of the Nordic Geodetic Commission NKG2016LU (see Vestøl et al. 2019), and its projection into the past. The two glacial variables relate to the model's fast component, composed by Påsse & Andersson (2005), which simulates the initial rapid land uplift right after the region was released from under the weight of the glacial ice (ice-model modified from Henry Patton's model, published in Sejrup et al. 2022).

The model has been calibrated to match 70% of sea-level index points throughout the Baltic region and coastal Norway published by Rosentau et al. (2021) and Creel et al. (2022) (see Hakonen 2025b). While the calibration is not yet perfected everywhere in Fennoscandia, the model is especially valid in Finland for the temporal range of up to 5500 BCE. The advantage of GLARE is in its GIS (QGIS software specifically) application straight onto DTMs so they can be transformed to simulate past landscapes.

Lake reconstructions

The DTMs, recalculated by set year, model lake tilting (e.g., Bergman et al. 2003) whereby regions of faster uplift overtake regions of slower uplift, forcing water systems to realign accordingly. Such water systems can be modelled as lakes in the regenerated DTMs by identifying the outflows of the lakes and setting the water level on the appropriate outflow elevation either as a reclassified raster layer or a vector contour. Here, vectors are used.

Where past shorelines are currently submerged, the DTMs require amendment with lake depth models. The depth models, fused with National Land Survey of Finland (NLSF) 10 metre elevation model (CC BY 4.0), were interpolated from official open-source water

depth points and contours (CC BY 4.0, SYKE; Traficom). The custom joint elevation and depth model was processed with GLARE to simulate the topography of the Finnish Lakeland in 500-year intervals from 6000 BCE to 2000 BCE.

The mean shorelines of Greater Päijänne and Saimaa lakes were regenerated from these processed DTMs at 500-year intervals to ascertain the effect of land tilting due to the sloping gradient of the land uplift rate. The power of the lake-tilt depends on the size of the lake, meaning generally that the smaller the lake, the lesser the effect. Here only the two largest lakes, Päijänne and Saimaa, were regenerated.

Drawing water routes using the land-/waterscape reconstructions

The main navigation routes between rock art sites were interpreted topographically and drawn manually in four regenerated land/-waterscapes: at 5500 BCE, pre-Vuoksi 4000 BCE, 3000 BCE and 2000 BCE. We picked two elements to act as the nodes for the main water routes: boat pictographs, which are the primary indicators of water travel, and amber finds (from the AADA dataset, see Pesonen et al. 2024), which are associated with sources in the southern Baltic and are thus intimately connected with long-distance travel (e.g., Núñez & Franzén 2011). Out of presently known pictographs in Finland, all the boat images are situated in the study region along and between the waterways of Päijänne and Saimaa (Kivikäs 2005: 29; 2009: 103; Mantere 2014: 27, 52). Mantere proposes that especially the elk-headed boat images were navigation aides to traverse the labyrinthine inland water routes (Mantere 2014: 54). In regions such as the Lake of the Woods in Canada, rock art in general has also been linked to travel routes (Norder & Carroll 2011). Gjerde (e.g., 2010: 410–6), for one, arrived at the same conclusion regarding Northern Fennoscandian rock art sites.

Amber finds are commonly dated to the Middle Neolithic (4000–2800 BCE), so they may not have affected water routes in 5500 and 2000 BCE, but these conjectural routes serve only in the background analysis to distinguish the changes in the landscape. In this sense the amber finds conceptually represent the "flat chronology" of Inner Finland, where dwelling sites often consist of multiperiod activity from the Mesolithic to the Early Metal Period (c. 1900 BCE to 300 CE). The boat figure nodes similarly represent a kind of circular logic, where the rock art was originally made in places which people visited or travelled through, and which drew in people when the rock art existed.

As lines drawn in water, the water routes themselves are merely hypothetical. The purpose of the analysis is not to establish the main water routes as fact, but to establish the measure of change to overall navigation due to lake-tilting.

Modelling the location of rock art panels with aerial lidar

The water levels of the two lakes were combined with local semi-3D visualisation of Saraakallio and Astuvansalmi processed from 0.5 points/m2 aerial lidar published by the NLSF (CC BY 4.0). As aerial lidar data is topographical, the visualisations miss the concave surfaces of the cliffs where the actual pictographs are located. Nevertheless, the topography is otherwise preserved and the approximate extents of the pictographs at the sites, especially their maximum and minimum elevations (see Kivikäs 1999) can be represented. The lidar data was processed into DTMs and visualised in perspective using QGIS 3D viewer. Overlays of lake vectors demarcate the mean level of the water at different temporal stages of the sites. The visualised surfaces were marked with a panel indicating the location of the main body of painted figures, which were set based on measurements reported by Kivikäs (1999: 32–35, 89–90 and corrected to current elevations). The panel at Saraakallio is marked here to 90.5–102.3 meters above current sea-level (m a.s.l.), while the Astuvansalmi panel is at 83.5–88.5 m a.s.l.

Palimpsest analysis

When discussing the chronology of the pictographs in Lakeland, an important indicator of continued use is the presence of palimpsests, i.e. overlaps. These can be, e.g., a cumulative palimpsest (superimposition of images over an existing image), a temporal palimpsest (where images have been clearly added later), a spatial

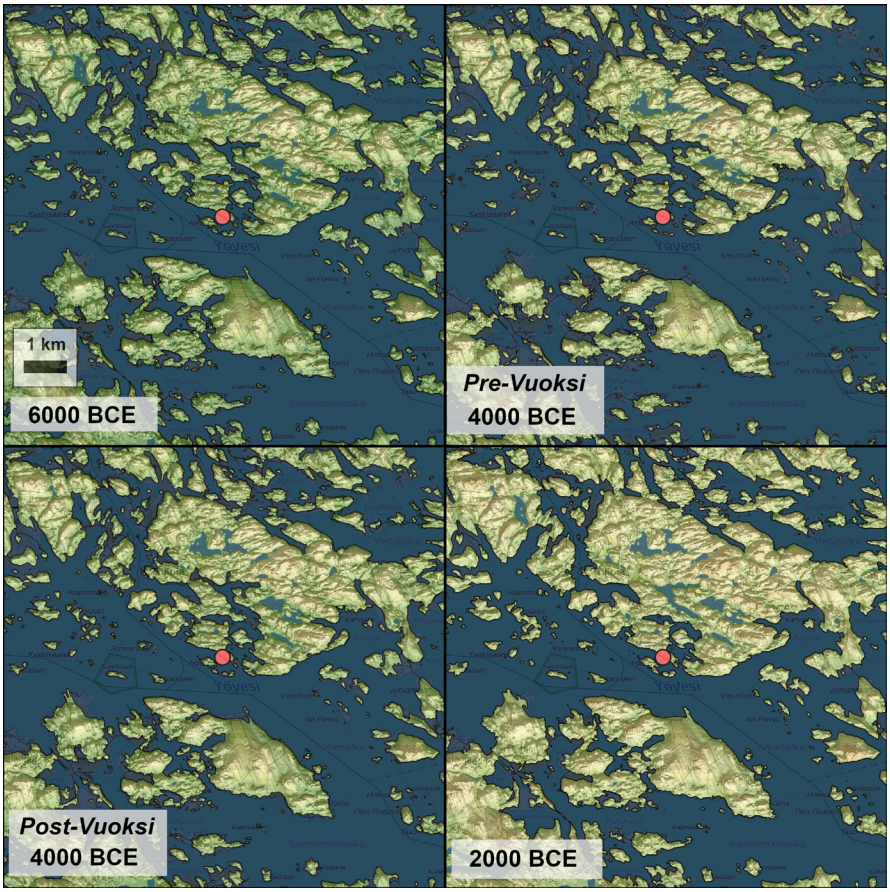

Figure 4. The changing landscape around Astuvansalmi. The comparison reveals relatively little change due to the steepness of the local topography. DTM modified from National Land Survey of Finland (NLSF) 10 m resolution elevation model. NLSF Topographic Map in the background (CC BY 4.0) © A. Hakonen.

palimpsest (where there are proximal associated sites) or a palimpsest of meaning (site re-uses and reconfigurations, such as a ritual site used over different periods with different cultural contexts, which suggests a recognition of the sacred power of the landscape) (Bailey 2007; Niskanen 2019). The palimpsest approach is further applied to selected pictographs to assess elements of continuity.

ANALYSIS AND RESULTS

Changing landscapes

Shoreline shifts in the Lakeland region depend mostly on the location of the studied area in relation to the primary outflow. The lesser the distance between the two, the less change is bound to occur. This is evident when comparing the topographies of the regions around Saraakallio and Astuvansalmi. Prior to 5500 BCE, Astuvansalmi was located 225 km south-southeast of the (Selkäydenjärvi) outflow of the Greater Lake Saimaa. The land channelling the outflow rose faster than the other parts of the lake, tilting the lake basin to the southeast and forcing more water there, which raised the water level at Astuvansalmi relatively fast. But, according to the model as well as prior research (see e.g., Hakulinen 2024: 117), between 5500–4500 BCE (a new iteration under testing shifts the range to 5200–4300 BCE) the waters overflowed several channels in the south, the closest one (Pieni-Varpanen) only 18 km to the west-southwest of Astuvansalmi, so the water level became stable.

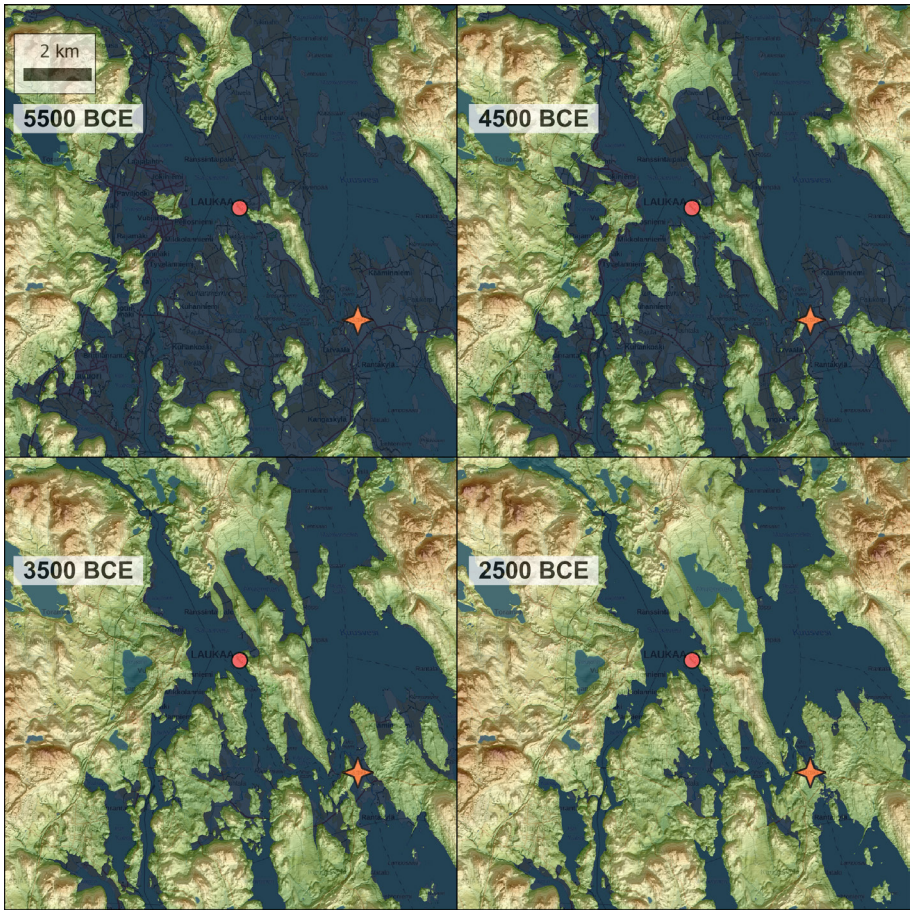

Figure 5. The changing landscape around Saraakallio in the centre. A major Neolithic dwelling and mortuary site Hartikka (orange star) is located 4 km to the southeast and according to the model it emerged from the waters between 4500–4000 BCE. DTM modified from NLSF 10 m resolution elevation model. NLSF Topographic Map in the background (CC BY 4.0). © A. Hakonen

To the southeast, though, water level continued to rise, eventually c. 4000 BCE bursting through the Salpausselkä moraine ridge and forming the Vuoksi River, which continues to be the main outflow of Saimaa to this day. This caused an initial water level drop of around 2 metres in Astuvansalmi (from Hakulinen 2024), followed by a gradual decline. The results of the model conform with the earlier narratives of Lake Saimaa history (e.g., Saarnisto 1970; Tikkanen 2002), with events, though more detailed than previously, largely concurring with earlier research (see e.g., Hakulinen 2012, 2024: 117).

In the region of Saraakallio, the gradual changes were much more dramatic. Before c. 5400 BCE the outflow of Greater Päijänne (Muurasjärvi-Kotajärvi) was located 134 km from Saraakallio to the north-northwest, forcing more water to the south as time went on. After the Heinolanharju Ridge – which the water masses effectively leaned on – burst open (see Hakulinen 2025; also, Tikkanen 2002), the new outflow (Vuolenkoski) formed 149 km to the south of Saraakallio. The result was relatively fast water level rise at Saraakallio prior to 5400 BCE, then a drastic drop of several metres (2.5 metres applied in this analysis, based on the observations made in Hakulinen 2025 of contemporary channels on a lower ridge) followed by a relatively fast water level decline, until the smaller lake at Saraakallio, Saraavesi, became isolated from

Päijänne sometime after 2000 BCE. The rate of erosion at the Vuolenkoski rapids after the centuries following the Heinolanharju outburst is unknown. In this paper the lake level above the rapids is set to have reached roughly the current level by 4000 BCE, but this may have actually occurred as early as 5000 BCE, making the water-level drop at Saraakallio in the centuries following 5400 BCE even more rapid.

Due to the differences in the local topographies, the general outline of the Astuvansalmi region's shorelines remained stable relative to Saraakallio's. The Western Saimaa archipelago is defined by steep inclines and cliffs that rise vertically above the waters, so the shoreline changes, even the abrupt one caused by the Vuoksi outburst, seem insignificant at a regional scale (compare Figs. 4 and 5). In Päijänne, in the Saraakallio region

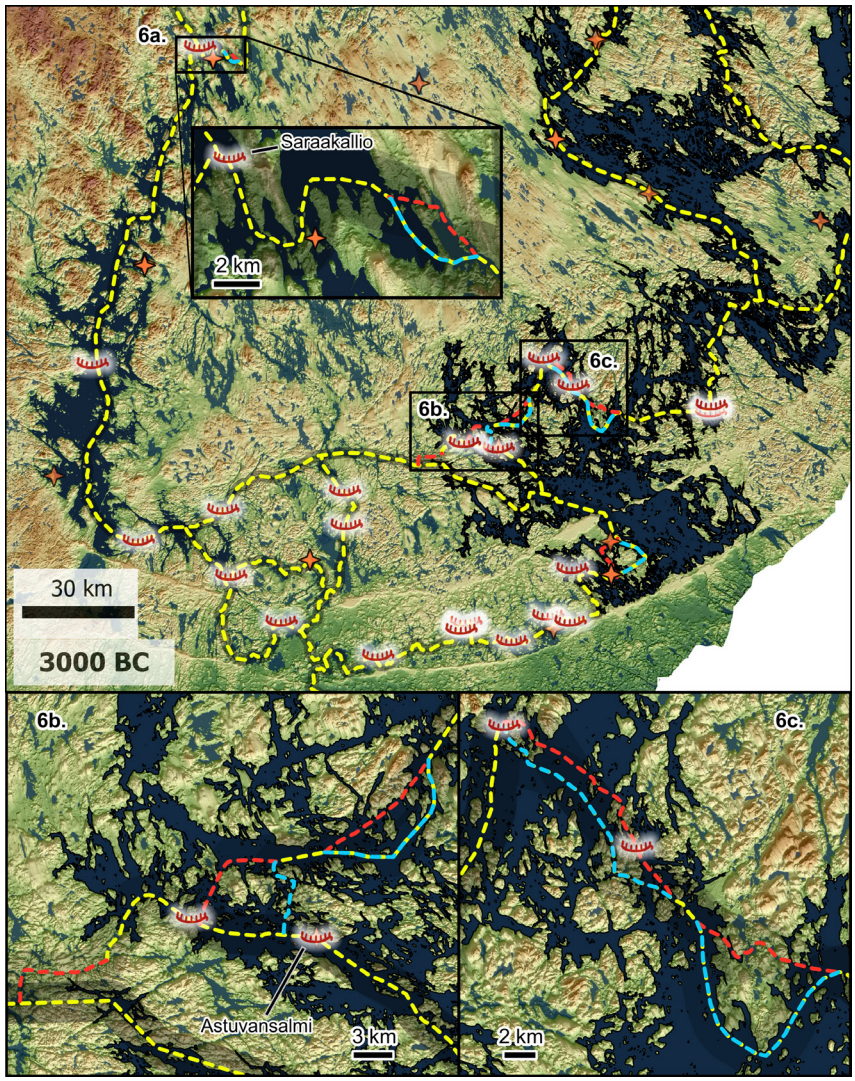

Figure 6. Hypothetical water routes through rock art sites containing boat figures (red boats) and Stone Age sites containing amber finds (orange stars) in 3000 BCE. Red routes were closed off after 4000 BCE, reforming into the cyan routes. Darker blue water areas represent the main lakes at the time simulated with GLARE. Other water areas are represented in their current form by Finnish Environment Institute (Syke) Ranta10-database. Amber finds extracted from AADA (Pesonen et al. 2024). DTM modified from NLSF 10 m resolution elevation model (CC BY 4.0). © A. Hakonen.

where the topography is less steep, the changes are obvious even on the regional scale. The trend in the region's landscape change is for the open waters of 6000 BCE to shrink into a maze of meandering waterways by 2000 BCE (see Fig. 6). The dramatic drop in water level c. 5400 BCE spawned new islands of considerable size within only a few years, a process that must have been astonishing to observe locally.

But even though the landscape change was more nuanced in the Astuvansalmi region, various changes would have still been obvious on the ground. In some places, previously passable water routes were cut off or became narrow or rocky. Many former islands became part of the mainland, and, in some places, travellers were forced to transport their boats across portages (Fig. 6). These changes forced adaptations to mobility and changed the nature of travel and related interaction.

Navigation

The changing water networks influenced patterns of movement, trade and communication. This has implications for understanding how the rock art sites were situated within cultural landscapes and how those networks evolved over time. In Fig. 6, hypothetical water routes for 4000 (pre-Vuoksi) and 3000 BCE are proposed, with rock art sites containing boat figures and prehistoric sites containing amber finds serving as nodes.

Comparison of the two waterway networks indicates local variation where the accessible routes may have shifted by tens of kilometres (Fig. 6b and 6c). Most of the changes were in the Lake Saimaa region, where several islands merged with others or the mainland. During this time the changes in Päijänne are much more subtle, with only local change in the routes observed around the region of Saraakallio (Fig.

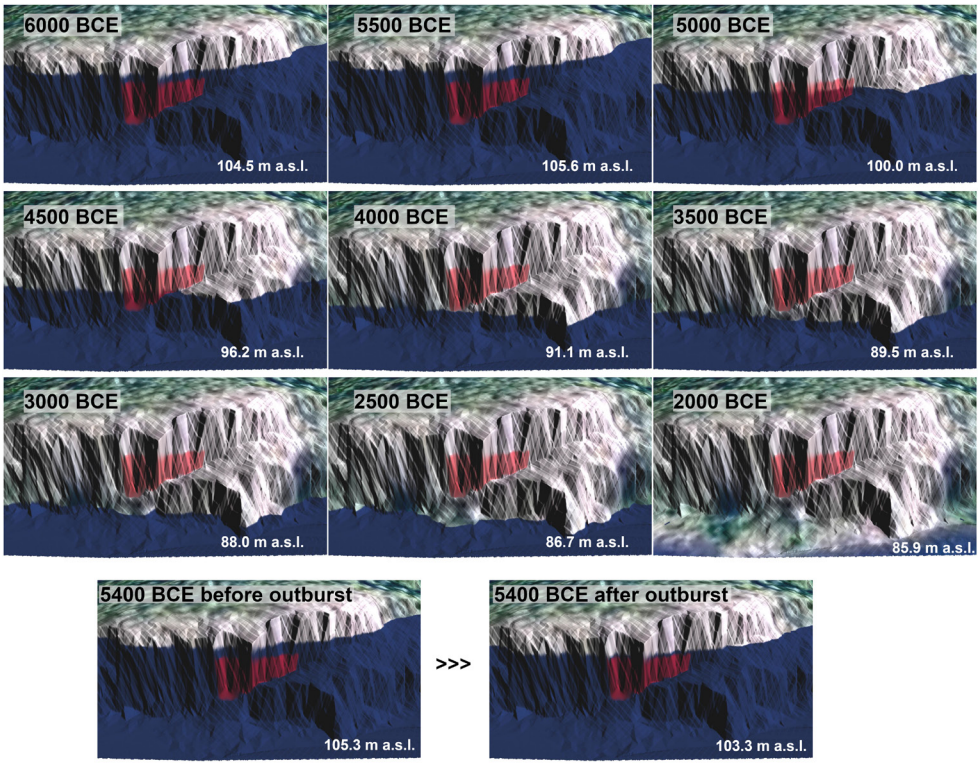

Figure 7. Approximate elevation zone of the (12-metre-tall) Saraakallio rock art panel in relation to the mean water level of Saraavesi at different times based on GLARE v. 2.2. Raw lidar data and orthophotography by NLSF (CC BY 4.0). © A. Hakonen.

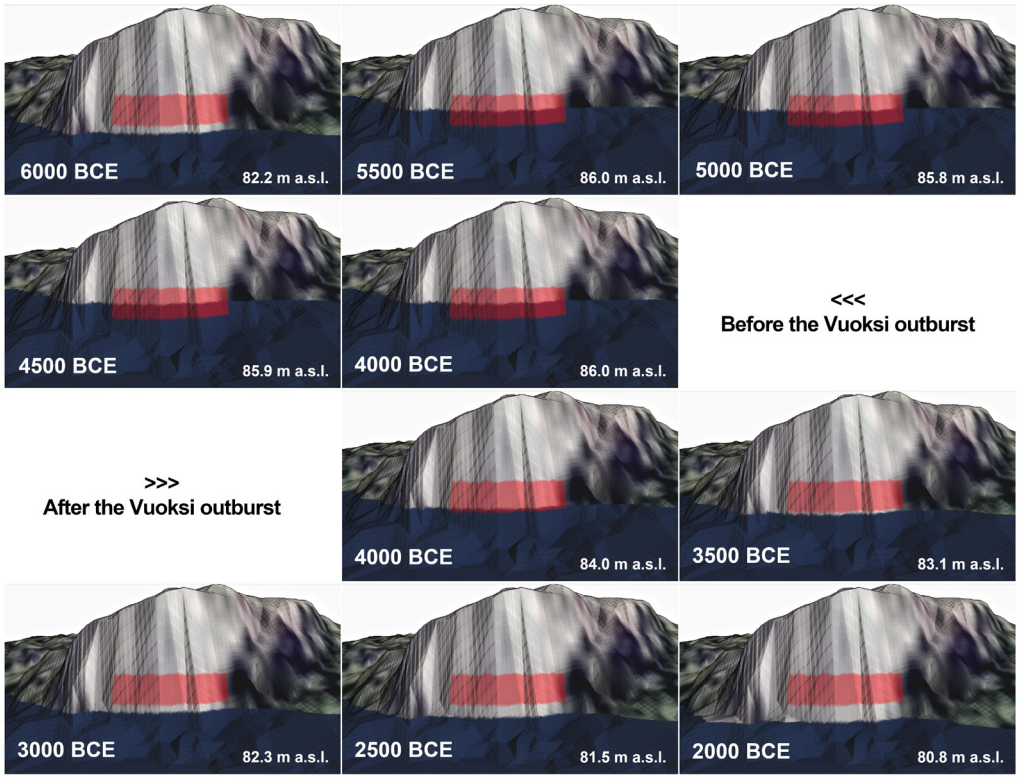

Figure 8. Approximate elevation zone of the (5-metre-tall) Astuvansalmi rock art panel in relation to the mean water level of Yövesi at different times based on GLARE v. 2.2. Raw lidar data and orthophotography by NLSF (CC BY 4.0). © A. Hakonen.

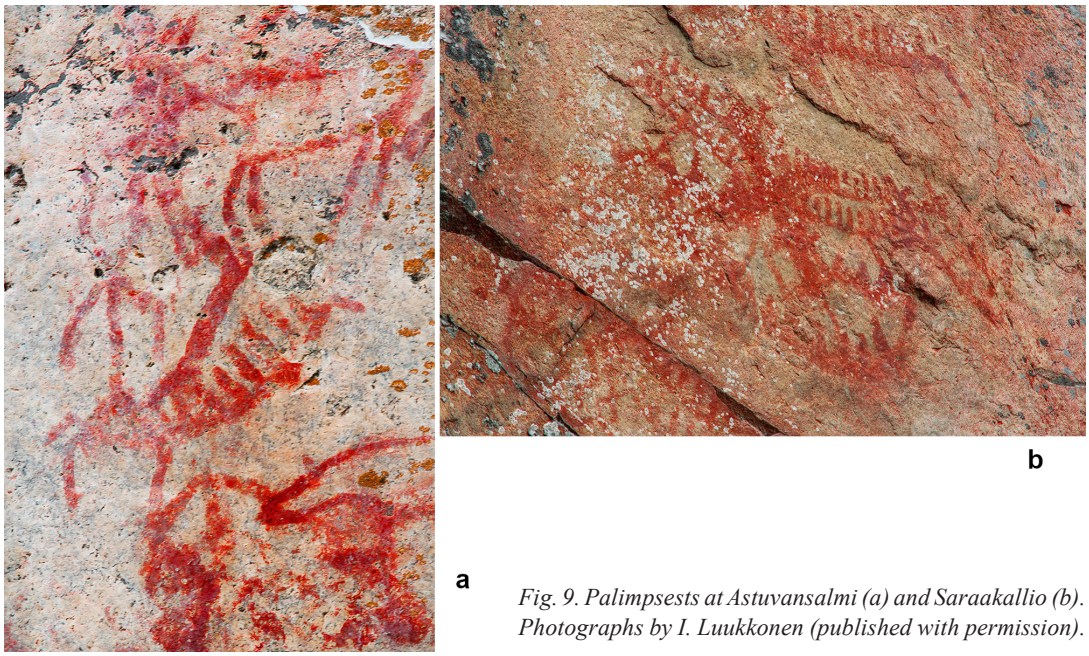

Fig. 9. Palimpsests at Astuvansalmi (a) and Saraakallio (b). Photographs by I. Luukkonen (published with permission).

6a), where dramatic shifts occur earlier in 5400–4000 BCE. Such shifts represent only the most obvious changes in the landscape as the blocking of water routes necessitate drastic geographic change. The landmarks along the routes also underwent changes that were visible wherever there were stable reference points, such as red ochre pictographs.

Water level fluctuation and palimpsests

In the Lakeland region, the use of rock art panels was regulated by the changes in the water level. Figures 7 and 8 show the simulated mean water level progression in 500-year intervals in relation to the panels of Saraakallio and Astuvansalmi. In Saraakallio, the cliff face was submerged at the onset, with the water level rising, but the cliff began to rapidly expose itself in the centuries after the Heinolanharju outburst of 5400 BCE. Applying a conservative estimate, at 5000 BCE upper phases of the panels would have been accessible via a cliff terrace on the waterline, and by 4000 BCE the panels became completely exposed. In contrast, the cliffs of Astuvansalmi were exposed during the Mesolithic, with the lower half submerging between 6000–5500 BCE. Around the time of the Heinolanharju outburst, Astuvansalmi may have reached its high-water mark where the water level stayed until 4000 BCE, when the Vuoksi outburst exposed almost the rest of the panel, and subsequently the water level descended, allowing the whole panel to be painted by 3000 BCE.

Note that Figures 7 and 8 show the mean annual water level, while the level that affects the preservation of red ochre paintings the most is the high annual water level. The high water today generally adds around +0.5 m to the mean water level, but in prehistory before water level regulation the added effect might have been, roughly estimated, closer to +1 m (cf. Keto et al. 2008: Table 2), while once-in-a-century extreme water level fluctuation could have been around

Figure 10. Astuvansalmi sleeping giant and amber pendants discovered from the lake (not in scale). The elevation line 86.0 m a.s.l. signifies the highest mean water level of Saimaa, with an estimated +/-1 m marking the annual extreme fluctuation (extreme once-in-a-century fluctuation is estimated at +/-2 m). Artefact archive numbers from left to right KM26331:2, KM27146:1, KM26331:1 and KM25771:1. Original photographs: Finnish Heritage Agency CC BY 4.0, modified by A. Hakonen.

+2 m as exemplified by the 1899 record flooding of both Saimaa and Päijänne (see e.g., Höytämö & Leiviskä 2009: 9; Hakulinen 2024: 6–7; 2025: 24).

The two sites in question contain the best evidence of a single rock art site being in use for a longer period by successive generations. The placement of the pictographs gives us two clues to the continuity of use. First, the presence of palimpsests, where new images overlap previous ones represents continued use and repeated engagement with the sites. At Astuvansalmi, examples of palimpsests are superimpositions: e.g., an overlaid human figure and a boat; an area painted over with a slightly different colour (Fig. 9a). Similarly, a superimposition is found in the Saraakallio painting site, for example an oblique cross and a boat image (Fig. 9b). Second, there is a range in heights of the paintings which indicates it was in use for a long time, resulting in a reverse stratigraphy, with older pictographs higher up on the cliffs and newer paintings created below these in 'horizons' as new surfaces were exposed. This is an important reflection of how the lowering water levels affected the practise of cliff painting. The site was used and re-used as the water level descended, leaving the Saraakallio paintings of today between 5.3–17.0 metres above the lake (Kivikäs 1999: 89), while the paintings in Astuvansalmi are 7.7–12.5 metres above the lake (Kivikäs 1999: 32).

DISCUSSION: GEOMYTHS AND MEMORY

There is a growing body of research engaging with the ontological status of rock art landscapes as agentive. As noted in a recent volume on contemporary approaches to rock art, 'Landscapes not only constitute the physical and ecological place of rock images, but they are active and sentient in an ontological way' (Moro Abadía & Chase 2024). This shift reflects broader trends across archaeology and anthropology toward acknowledging non-human agency and the relational structuring of place (see e.g., Herva & Lahelma 2020). Such relationality is especially pertinent in the context of forager peoples. For example, among the Paiutes of Northwest America children were taught from young age to watch and listen to the world, water and air for guidance and to learn what the world wishes (Stoffle et. al 2024: 131). It is these kinds of relationships which bring us to consider the prehistoric world of the north through geomythology.

Discussing the results from the perspective of geomyths provides a crucial link between simulated geographic change and the relationship that humans had with the actual changes. Intentionally or not, cliff paintings encoded knowledge of the landscape's transformations, anchored cultural memory and recorded shared experiences, communicating these either implicitly or explicitly (see also Gjerde 2010: 438–441). Indeed, significant environmental events are often featured in myths and legends, preserving their legacy within cultural memory (Piccardi & Masse 2007).

Geomyths are stories passed down to describe and explain natural events such as flooding or rapid birth of new land (Vitaliano 1968; 1973; 2007). These geomyths are inscribed in the landscape. The transfer of geological events into meaningful stories and symbolic images reflects the interplay between environmental knowledge and cultural identity (Barber & Barber 2004; Nunn & Reid 2016; Nunn 2018; 2020; 2021; Nunn et al. 2021). The challenges posed by rising land, shifting waters and changing travel routes will have been reflected in oral traditions for many generations. As post-glacial land uplift gradually transformed the shorelines and exposed new rock surfaces, the landscape changes were witnessed and likely remembered as geomyths across generations. Especially extreme events such as the outbursts of Heinolanharju and Vuoksi, which changed the waterscapes dramatically, would have been part of the collective memory. Pictographs created on newly exposed rock faces may be interpreted partly as geomythic expressions – material traces of narratives that encode human responses to environmental transformation.

Besides the mnemonic function of the sites, it can be argued that among their many roles are navigational and mobility aids encoded into the placement of the paintings (see e.g., Gjerde 2010: 409–416). Rock art studies in North America have discussed how redundancy in visual motifs can reduce ambiguity and ensure clarity of the message for wayfinding. For example, in the region of the Colorado River

petroglyph-enhanced boulders acted as reference points for travellers on long journeys. As Hartley (1992) reports, these petroglyphs functioned as 'reference stimuli for storing information about spatial locations and wayfinding.' Hartley & Wolley Vawser (1998: 206) further conclude that 'rock-art in prominent topographical situations functioned as one medium of information available for coping with the mobility demands of [the] environment.' Hawley & Wolley Vawser suggest that sites with a larger number of images acted as aggregation sites, a notion that Gjerde (2010: 409), in the context of Fennoscandian rock art, agrees with. Interpreted in this light, since both Saraakallio and Astuvansalmi have large numbers of images, they may have had similar roles as aggregation sites, which would mean that the changes that occurred in these places would have been witnessed by more people than most other rock art sites.

In Astuvansalmi the changes would have been made especially potent by the gigantic anthropomorphic profile of the cliff face (See Fig. 10.). Due to the angle of capture of the applied lidar data, the 'Sleeping Giant' profile at Astuvansalmi is not visible in Fig. 6. The jawline of the giant (Fig. 10) is just below the middle elevation of the depicted panel. The giant would have been visible for Neolithic visitors to the site, who must have also perceived its presence. The face seems to have hung above the waters prior to 5000 BCE with the water level rising above its chin and remaining there for a millennium, before the newborn Vuoksi River began to drain water and lower the lake level. Visitors to Astuvansalmi would have in their lifetime witnessed the giant slowly emerging from the water as the lake itself imperceptively tilted. Low water fluctuation by 3500 BCE would periodically reveal the throat of the giant, giving a glimpse of its humongous body that would have been perceived as remaining hidden by the waters.

Underwater archaeological investigations in the lake in front of the Astuvansalmi giant and its adjacent panels uncovered three anthropomorphic amber pendants with faces not unlike the giant's profile as well as a bear-shaped amber pendant (Grönhagen 1991, 1994; Fig. 10). These finds may exemplify the notion that animacy in the landscape was a perceived element. A landscape in motion may well have been understood as being imbued with supernatural power or populated by extraordinary animate beings. It is likely that the witnesses recognised the movement at Astuvansalmi since they returned there over many generations and added to the paintings, as indicated by the palimpsests. It is probable that there were also oral traditions about the rising of the giant. Several other cliff painting sites – at least 26 – have also been noted as having anthropomorphic or zoomorphic features (Lahelma 2008b; Miettinen 2000, 2004; Pentikäinen & Miettinen 2003; Taskinen 2006). Among these at least Taskinen lists Saraakallio, although no other author mentions the site having such features. It should be recognized though that rock surfaces regularly emit patterns that produce a pareidolic effect of which some people are more receptive to interpreting as meaningful (e.g., Zhou & Meng 2021; Wang et al. 2022).

There is no direct link from the traditions of 18th- and 19th-century Finnish-Karelian rural communities and their beliefs to the Neolithic period, nor is there a direct link to the North American examples discussed earlier. Nevertheless, there are some elements of animism in folklore accounts that inform us of how humans in general may sometimes understand and interact with a power-charged and animate landscape, and with cliffs in particular. The cosmology represented in the Finnish-Karelian folklore refers to *väki* as the supernatural force in nature. Such power was seen to inhabit both natural and cultural elements, ranging from iron tools and cemeteries to the forest, water, fire, and cliffs (Stark-Arola 2002: 68). The *väki* in cliffs was considered especially strong, and it could only be overpowered by water *väki* (here one considers the movement of water and cliffs in the Lakeland). The interaction of opposing *väki* – such as the powerful cliffs and the water that shapes them – may reflect an understanding of the landscape as an active, contested, and relational environment.

A particularly powerful *väki* was attributed to crying cliffs. Such cliffs are described as perpetually wet. Water constantly seeps from

cracks in the cliff, and often the water is red from oxide in the rock. According to an informant from Archangel Karelia in 1889, power could be gained from a crying cliff by following certain procedures, including depositing three silver coins, reciting an incantation, requesting the rock for its *väki* with flattering words, and taking small pieces of the rock (Stark-Ahola 2002: 72). The similarity between the silver coin offerings to the crying cliffs in this account and the anthropomorphic amber pendants found at Astuvansalmi suggests a similar practice of negotiating power with animate landscape features through material offerings. Likewise, later ethnographic reports recorded beliefs in the sentience of Sámi sieidi stones and cliffs, which were understood as living beings with whom people communicated via ritual offerings (Lahelma 2008b; Äikäs 2015). In these accounts of intersubjectivity, the sieidi stones and cliffs made sounds, expressing for example pride, anger, and vengefulness, and were even known to shout, laugh or sing (Paulaharju 1932; Manker 1957: 34; cf. Rainio et al. 2018, 2024). This arguably constitutes geomythic expression. With cliff painting sites, it seems unlikely that such geomyths would have had their actors forever bound and immobile in the rock, especially since motion – both gradual and sudden – played such a powerful role in the landscape.

CONCLUSIONS

This study argues that prehistoric pictograph sites of Finnish Lakeland acted both as actual and metaphoric signposts in navigating the challenges posed by post-glacial rebound. As the land uplifted and tilted, transforming water routes, these sites became crucial markers not only for human navigation but also for the broader human-environment interaction. The landscape itself exhibited agency, reshaping the environment and altering mobility, with people responding in special places through the creation and observance of rock art traditions.

The analysis illustrates how post-glacial land uplift reshaped shorelines and waterways over millennia. As shorelines retreated and water routes shifted, previously prominent locations along waterways may have lost their ritual, navigational, or settlement significance, while new areas emerged as focal points. Especially the increasing narrowing of river routes necessitated adaptation. One way to communicate safe routes to travellers in the water paths is with prominent pictographs, which appear to be situated at important locales along water routes.

As the waterscape was changing, the human response to this transformation included traditions – such as rock art production – which continued over generations. This persistence reflects how communities observed and adapted to their shifting environment, possibly encoding these transformations into myths, oral traditions, and visual records. The rise of the cliffs might itself be encoded in the creation of new images in horizons and represents a cultural narrative that records the awareness of the changed landscape. The pictographs arguably functioned as both navigational tools and as cultural markers, encoding knowledge of the shifting landscape. Read this way the pictographs functioned as a communal memory of the landscape transformation for generations to come.

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CHALLENGES OF ANCIENT DNA PRESERVATION IN FINLAND: A REPORT ON UNSUCCESSFUL SAMPLES

Abstract

Ancient DNA (aDNA) research has rapidly expanded our understanding of past populations, yet its success remains highly dependent on biomolecular preservation. This article presents negative sampling outcomes from 85 individuals in Finland, sampled between 2017 and 2022. These individuals represent sampling efforts that failed to yield data for human population genetic analyses, corresponding to a success rate of approximately 44%. The failed dataset includes samples from a wide temporal and geographical range, from Bronze Age contexts to post-medieval burials, and notably, some of Finland's most iconic archaeological individuals. Our findings align with previous studies and show that the petrous part of the temporal bone and teeth consistently outperform other skeletal elements in human DNA preservation. Preservation also varied by region, and possibly also by burial environment and post-excavation storage history.

Keywords: aDNA, sampling strategies, DNA preservation, DNA degradation

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INTRODUCTION

Ancient DNA (aDNA) research has increased our understanding of past populations and individuals, but its success depends on DNA preservation. In response to both the promise and the limitations of this field, several initiatives have been launched to explore genetic histories across different regions. One such effort is the Sugrige project, an interdisciplinary research initiative launched in 2016 with the aim of collecting aDNA samples from North-western Eurasia to study the genetic history of Uralic-speaking populations. The work started in the Sugrige project is continued in the Sumragen project that focuses on Iron Age individuals in Finland, as well as in Human Diversity, an interdisciplinary University of Turku Profilation Profi7 project (https://sites.utu.fi/humandiversity/).

The research outputs of Sugrige/Sumragen have addressed several areas of aDNA research. These include reconstructions of population movements and interactions over time (Lamnidis et al. 2018; Översti et al. 2019; Peltola et al. 2023; Nordfors et al. 2025a), the study of individual life histories by combining archaeological, genetic, and historical evidence (Moilanen et al. 2022b; Rohrlach et al. 2024; Nordfors et al. 2025b; Peltola et al. in prep.), and contributions to the study of ancient pathogens (Majander et al. 2020; Kocher et al. 2021; Michel et al. 2024).

Many of the project's samples have provided valuable genetic data from ancient humans, including pathogen DNA, that contribute to ongoing and future studies. However, several samples have not yielded usable genetic data. Between October 2017 and August 2022, a total of 193 individuals were sampled – some from different skeletal elements – at the Max Planck Institute for the Science of Human History (now Max Planck Institute for Geoanthropology) in Jena, Germany. Of these individuals, 85 yielded DNA data suitable for human population genetic analyses, resulting in a success rate of approximately 44%.

In this paper, we report the previously unpublished set of samples that failed to yield sufficient genetic data (Table 1, SI, Fig. 1). These negative results provide valuable information for future sampling, as they clarify whether particular individuals or skeletal elements have already been sampled, how, when, and where the DNA analysis was done and what methods were used in the laboratory. This information helps other researchers decide whether these individuals or skeletal elements should be re-analysed in the future using improved techniques. The reporting also responds to the public interest in aDNA research, such as frequent inquiries about specific sampled individuals and sites. Additionally, we use the dataset at hand to explore potential factors that may play a role in favourable DNA preservation in Finland, which helps researchers to make better-informed decisions for sampling new sites and individuals in the future.

While the general principles of aDNA preservation are quite well established, systematic data on retrieval success from Finnish archaeological contexts remain unpublished. The environmental and cultural conditions in Finland (acidic soils and a long tradition of cremation) pose challenges distinct from many other European regions. By presenting a comprehensive dataset of unsuccessful samples alongside the successful ones, our study provides quantitative success rates, site-level comparisons, and skeletal element-specific outcomes that are essential for refining sampling strategies in low-preservation environments.

MATERIALS AND METHODS

Sampling was conducted at the aDNA facility at the Max Planck Institute of Geoanthropology (formerly the MPI for the Science of Human History) between October 2017 and August 2022). Skeletal elements selected for sampling were briefly exposed to UV light to reduce surface contamination, and bone powder was drilled from the samples for DNA extraction (Neumann et al. 2020; Orfanou et al. 2020).

DNA was extracted from the bone powder following a manual protocol (Dabney et al. 2013; Velsko et al. 2020). In brief, c. 50 mg of bone powder was combined with an extraction buffer containing 0.45 M EDTA and 0.25 mg/ml proteinase K, and the reactions were incubated at 37 °C on rotation overnight, after which DNA

was purified in silica columns. Since 2020, an automated protocol has been used (Rohland et al. 2018), with purification from 150 ml of lysate using silica-coated magnetic beads and binding buffer D.

DNA extracts were converted into Illumina sequencing libraries. Before autumn 2020, the manual double-stranded protocol described in Meyer and Kircher (2010) and Aron et al. (2020) was used. DNA was treated with uracil-DNA-glycosylase to partially remove post-mortem DNA damage (UDG-half). Libraries were tagged with sample-specific indices to allow for parallel sequencing (Kircher et al. 2012). In autumn 2020, extraction and library preparation protocols were updated to automated protocols, and the standard library build was changed from double-stranded UDG-half to a single-stranded protocol without UDG treatment, described in Gansauge et al. (2017; 2020).

Libraries were sequenced on Illumina HiSeq 4000 or HiSeq 2500 to ~5 million reads, with paired-end or single-end setups, to assess DNA preservation. In the bioinformatic processing, adapter sequences were removed with leeHom (Renaud et al. 2014), and the sequencing reads were mapped to the human reference genome hs37d5 using bwa aln (Li & Durbin 2010), with parameters adjusted for aDNA (-n 0.01 -o 2 -l 16500). The fraction of C-to-T transitions in the terminal positions of the fragments was calculated to allow for qualitative estimation of DNA authenticity.

For most of the project, the cut-off for sufficient DNA preservation was 0.1 % of endogenous DNA, i.e. reads mapping to the human genome, which nearly all of the samples presented here failed to reach. In three cases, non-UDG libraries passed the endogenous DNA threshold but were excluded due to a lack of deamination, which we expected to be ≥5% in non-UDG libraries. In a handful of cases, samples with lower endogenous DNA% (0.05-0.1%) were passed on to human DNA capture (Fu et al. 2015; Mathieson et al. 2015) if the sample was of special interest. This was the case for 16 samples; only three produced usable data (≥20,000 genome-wide markers out of the 1,24M markers covered by the capture panel). Moreover, at least one of the three showed signs of contamination. We also report five samples that exceeded the cutoff for endogenous DNA% yet failed to yield usable data after capture.

To assess the effects of a combination of factors that may contribute to human DNA preservation in Finland, we used a generalised linear mixed model. We included skeletal element, sample age, and library build as explanatory variables with fixed effects on successful human DNA recovery, and archaeological site as a random effect. For simplicity, we modelled DNA recovery as a binary outcome (success/failure), so the results reflect the likelihood of obtaining any amount of analysable human DNA and do not take into account variation in data quality among successful samples.

FAMOUS FINDS

The samples that did not have sufficient human DNA preservation for genetic analyses include some of Finland's most iconic archaeological finds, such as the Viking Age (c. 800–1050 CE) grave 56 from Eura Luistari, known as the burial of the "Eura matron" (sample IDs LUI002 and LUI027), and an Early Medieval (c. 1050–1250 CE) grave 1/1893 at Perniö Yliskylä (now part of the Salo municipality) (sample PYL005). Both graves have been used as the basis for reconstructions of Iron Age Finnish dress – the Eura and Perniö costumes, which play an important role in public representations of the country's Late Iron Age (Mäkelä & Kunnas 2025). A later costume reconstruction, the so-called Masku costume, is based on grave 32/1925 at Masku Humikkala (Tomanterä 1984). The sample (MAH010.A) from this grave has also failed to yield DNA.

Another famous example is grave 30/1955 at the Medieval cemetery of Mikkeli Visulahti. It is an undated cattle grave known in literature as the "sacrificial ox of Mikkeli" (Fig. 2) (Leppäaho 1957: 16 - 17; Kivikoski 1961: 271; Taavitsainen 1990). While Taavitsainen (1990) has interpreted the find as possibly post-medieval and unrelated to the cemetery, Kivikero (2011: 16) has argued that the preservation of the animal does not differ from the site's Iron Age remains. A human mandible with teeth – possibly from a disturbed burial – was found directly beneath the ox skull during excavation. However, no usable DNA

Table 1. List of archaeological human bone samples from Finland that have failed to yield usable aDNA. The table does not include repeat extraction attempts from the same sample. These, along with additional contextual and technical details, are provided in the Supplementary Table. Chronological abbreviations used: BA - Bronze Age (c. 1500 - 500 BCE), RP = Roman Period (c. 1–400 CE), MiP = Migration Period (c. 400–600 CE), EIA = Early Iron Age (c. 500 BCE–700 CE) MeP = Merovingian Period (c. 600–800 CE), VA = Viking Age (c. 800–1050 CE), LIA - Late Iron Age (c. 700–1100 CE) EM = Early Medieval (c. 1100–1250 CE), M = Medieval (c. 1250–1550 CE), PM = Post-Medieval (1550–).

Municipality	Site	Context	Dating	Museum ID	Sample ID	Sampled Bone
Åland, Eckerö Storby	Ec 6.32	Cairn	EIA	ÅM 235:1	MEL001	Two hand phalanges
Åland, Eckerö Storby	Ec 6.32	Cairn	EIA	ÅM 235:5	MEL003.A	Permanent molar
Åland, Eckerö Storby	Ec 6.32	Cairn	EIA	ÅM 235:5	MEL003.B	Permanent incisor
Åland, Eckerö Storby	Norra gravfältet i Västra Nabbergen, E 6.6	Cairn	EIA	ÅM 176:12a	MEL004.A	Femur
Åland, Eckerö Storby	Norra gravfältet i Västra Nabbergen, E 6.6	Cairn	EIA	ÅM 176:12b	MEL005.A	Femur
Åland, Eckerö Storby	Norra gravfältet i Västra Nabbergen, E 6.6	Cairn	EIA	ÅM 176:13	MEL006.A	Talus
Åland, Finström Godby	Fi 8.11	Mound cemetery	LIA	ÅM 525:118	GBV002.A	Femur
Åland, Saltvik Långbergsöda	Glamilders, Sa 20.8	Stone Age settlement site	3300– 2300 BCE	KM 4784:524	GLA001.A	Phalanx hand
Åland, Saltvik Långbergsöda	Glamilders,Sa 20.8	Stone Age settlement site	3300– 2300 BCE	KM 8679:229	LAB001.A	Femur
Eura	Eläinlääkärin tontti 50010026	Inhumation	MeP	KM 9411:5	EUR001.A	FDI 17
Eura	Vanha kansakoulu (Kaunismäki) 50010016	Grave 17/1987	LIA	KM 24007:123	EU1003.A	Cranium
Eura	Vanha kansakoulu (Kaunismäki) 50010016	Grave 7/1987	LIA	KM 24007:112	EU1004.A	Pars petrosa
Eura	Käräjämäki-Osmanmäki 50010027	Inhumation	LIA	KM 2700:37	KR1001.A	Phalanx foot
Eura	Käräjämäki-Osmanmäki 50010027	Inhumation	LIA	KM 4633:156	KR2002.A	Phalanx hand
Eura	Käräjämäki-Osmanmäki 50010027	Inhumation	LIA	KM 4633:101	KR2002.A	Ulna
Eura	Käräjämäki-Osmanmäki 50010027	Grave 6/1912 (Double burial)	LIA	KM 6127:30	KR3001.A	Cranium

Municipality	Site	Context	Dating	Museum ID	Sample ID	Sampled Bone
Eura	Käräjämäki-Osmanmäki 50010027	Grave 2/1912	LIA	KM 6127:55	KR3002.A	Fibula
Eura	Käräjämäki-Osmanmäki 50010027	Grave 5/1966	MeP	KM 17250:345	KR4001	Two hand phalanges
Eura	Luistari 50400001	Grave 335 (Possibly a triple burial)	MeP	KM 18000:3777	LUI001.A	Pars petrosa
Eura	Luistari 50400001	Grave 56 (Eura matron)	VA	KM 18000:1776	LUI002.A	Pars petrosa
Eura	Luistari 50400001	Grave 56 (Eura matron)	VA	KM 18000:1776:1	LUI027.A	Premolar
Eura	Luistari 50400001	Grave 295 (possibly a multiple burial)	VA	KM 18000:3450	LUI028.A	FDI 37
Eura	Luistari 50400001	Grave 20	MeP	KM 18000:1231	LUI029.A	Humerus
Eura	Luistari 50400001	Grave 285	VA	KM 18000:3269	LUI030.A	FDI 37
Eura	Luistari 50400001	Grave 30	MeP	KM 18000:1394	LUI031.A	Femur
Eura	Luistari 50400001	Grave 95	VA	KM 18000:2095	LUI032.A	Mandible
Eura	Luistari 50400001	Grave 435	MeP/LIA	KM 22346:41	LUI033	Pars petrosa
Eura	Luistari 50400001	Grave 998	MeP	KM 25480:624	LUI034	Pars petrosa
Eura	Luistari 50400001	Grave 331	MeP	KM 18000:3748	LUI037	Phalanx hand
Eura	Luistari 50400001	Grave 1062	MeP	KM 26695:25	LUI038	Phalanx hand
Eura	Pappilanmäki	Grave 20/1939	LIA	KM 11063:764 or 762	EUP001.A	Radius
Eura	Pappilanmäki	Grave 4/1939	LIA	KM 11063:300	EUP002.A	Ulna
Eura	Pappilanmäki	Grave 9/1939	LIA	KM 11063:569	EUP003.A	Phalanx hand
Eura	Yli-Nuoranne	Grave 2/1965	LIA	KM 16950:72	YLI001	Tibia
Eura	Yli-Nuoranne	Grave 3/1965	LIA	KM 16950:134	YLI002	Phalanx hand
Hattula	Myllymäki	Possibly an Iron Age settlement	LIA	KM 19704:1021	MYL002.A	Permanent molar
Hattula	Ruskeenkärki 82010021	Cairn	VA	KM 13777:6	RSK003.A	Pars petrosa
Hattula	Ruskeenkärki 82010021	Cairn	VA	KM 13777:6	RSK003.B	Long bone
Hämeenlinna	Eerola 2 855010004	Cairn	-	KM 22185:1	HME001.A	Cranium
Helsinki	Senaatintori	Grave 238	PM	NA	HKI006.A	FDI 47

Municipality	Site	Context	Dating	Museum ID	Sample ID	Sampled Bone
Ii	Illinsaari Suutarinniemi 1000019094	Grave 2/2013	EM	KM 39519:227/231	ILS003.A	Humerus
Ii	Illinsaari Suutarinniemi 1000019094	Grave 14/2014	EM	KM 40370:137	ILS004	Two permanent molars
Ii	Illinsaari Suutarinniemi 1000019094	Grave 12/2014	EM	KM 40370:135	ILS005.A	Pars petrosa
Isokyrö	Niemenmaanmäki 152010008	Cairn	MiP	KM 10851:8	NMM001.A	FDI 32
Joensuu	Kousanniemi Ollukkala 45010005	Stray find	PM	KM 28707:6	OLL001.A	Radius
Joroinen	Kalmasaari 1000015010	Burial island	PM	KM 20578:1	JOR001.A	FDI 47
Kaarina	Ristimäki I-II 853010004	Inhumation	LIA	KM 14349:50	RIT001.A	Cranium
Kemiönsaari	Jordbro 40010015	Cairn	BA?	KM 2503A:22	DRF001.A	FDI 27
Kokemäki	Leikkimäki (Äimälä) 271010038	Inhumation or unsuccessful cremation	LIA	KM 2294:30	KLM001	Femur
Kokemäki	Perävainionmäki 271010015	Cairn 1	LIA?	SatM 17824:57	KOI002.A	FDI 47
Kuopio	Kuusikkolahdenniemi 297010010	Cairn	BA	KuM 6154:21:6	KUO001	Phalanx hand
Masku	Humikkala 481010002	Grave 31/1925	EM	KM 8656:31:1a	MAH001.A	Cranium
Masku	Humikkala 481010002	Grave 21/1925	EM	KM 8656:6	MAH002.A	FDI 45
Masku	Humikkala 481010002	Grave 41/1925	EM	KM 8656:5	MAH003.A	FDI 17
Masku	Humikkala 481010002	Grave 44/1925	EM	KM 8656:16	MAH004.A	Tibia
Masku	Humikkala 481010002	Grave 22/1925	EM	KM 8656:1	MAH005.A	Cranium
Masku	Humikkala 481010002	Grave 16/1925	EM	KM 8656:11	MAH006.A	Tarsal bone
Masku	Humikkala 481010002	Grave 9/1925	EM	KM 8656:18	MAH009.A	Femur
Masku	Humikkala 481010002	Grave 32/1925	EM	KM 8656:2	MAH010.A	Cranium
Masku	Humikkala 481010002	Grave 46/1925	EM	KM 8656:1	MAH012.A	FDI 36
Masku	Humikkala 481010002	Grave 35/1925	EM	KM 8656:2	MAH013.A	Pars petrosa
Masku	Humikkala 481010002	Grave 30/1925	EM	KM 8656:15	MAH014.A	Tibia

Municipality	Site	Context	Dating	Museum ID	Sample ID	Sampled Bone
Masku	Humikkala 481010002	Grave 1/1966	EM	KM 16575:32	MAH015.A	Cranium
Mikkeli	Visulahti kalmisto 491010003	Grave 3/1954	EM	KM 13441:43	MK1001	Long bone
Mikkeli	Visulahti kalmisto 491010003	Grave 4/1955	EM	KM 13769:1	MK2002	FDI 48
Mikkeli	Visulahti kalmisto 491010003	Grave 30/1955	EM	KM 13769:182	MK2007	FDI 15
Mikkeli	Visulahti kalmisto 491010003	Grave 29/1955	EM	KM 13769:176	MK2008	Ulna
Nakkila	Penttala 531010020	Inhumation	RP	KM 5851:68	NAP001.A01	Pars petrosa
Nakkila	Penttala 531010020	Inhumation	RP	KM 5851:127	NAP002.A	FDI 48
Nakkila	Penttala 531010020	Inhumation	RP	KM 5577:32	NAP003.A	FDI 18
Nokia	Hakamäki 536010021	Grave 1/1922	EM	KM 8037:4	PRK002	Cranium
Närpiö	Edsbacken 545010013	Cairn, Grave 10	RP, Mip	KM 10888:25	NED001.A	FDI 16
Pori	Leppänen 609010011	Cairn	RP	SatM 17319:7b	POI1001.A	Femur
Pori	Leppänen 609010011	Cairn	RP	SatM 17319:16	PO1002.A	Femur
Pori	Leppänen 609010011	Cairn	RP	SatM 17319:37	PO2001.A	Tibia
Porvoo	Pikku Linnamäki 612010025	Grave 5/1967	RP	KM 17446:4	PPL001	Ulna
Porvoo	Pikku Linnamäki 612010025	Grave 4 or 5	RP	KM 17145:13c	PPL002	Ulna
Pälkäne	Kokkostenkärki 635010024	Cairn	-	KM 9120:12	PKK001.A	Femur
Pälkäne	Kokkostenkärki 635010024	Cairn	-	KM 9221:55	PKK002.A	Cranium
Raasepori	Kroggårdsmal-men 220010058	Tarand grave 4/1937	RP	KM 10612:28	RAS001.A	FDI 18
Raasepori	Kroggårdsmal-men 220010058	Tarand grave 1/1932	RP	KM 9536:3	RAS002.A	Radius
Raisio	Kansakoulunmäki 680010001	Grave 12/1959	EM	KM 14676:271	RK2001.A	Femur
Raisio	Kansakoulunmäki 680010001	Grave 7/1959	EM	KM 14676:241	RK2005.A	FDI 16
Raisio	Kansakoulunmäki 680010001	Grave 23/1960	EM	KM 15357:31	RK3001.A	Femur
Raisio	Kansakoulunmäki 680010001	Grave 21/1960	EM	KM 15357:27	RK3002.A	Pars petrosa
Raisio	Kansakoulunmäki 680010001	Grave 24/1960	EM	KM 15357:44	RK3003.A	FDI 45

Municipality	Site	Context	Dating	Museum ID	Sample ID	Sampled Bone
Raisio	Kansakoulunmäki 680010001	Grave 24/1960	EM	KM 15357:51	RK3004.A	Femur
Raisio	Tuomala 680010008	Inhumation	LIA	KM 19000:8776	RAI001.A	Pars petrosa
Salo (Perniö)	Yliskylän hautausmaa 586010010	Grave 5/1893	EM	KM 2912:87	PYL001	Ulna
Salo (Perniö)	Yliskylän hautausmaa 586010010	Grave 1/1893	EM	KM 2912:48	PYL005	Tarsal bone
Salo (Perniö)	Yliskylän hautausmaa 586010010	Grave 6/1893	EM	KM 2912:92	PYL007	Vertebra
Salo (Perniö)	Yliskylän hautausmaa 586010010	Grave 7/1893	EM	KM 2912:107	PYL008	Tibia
Salo (Halikko)	Rikalanmäki 73010022	Grave F/1950	EM	KM 12690:160	SIK002	FDI 46
Salo (Halikko)	Rikalanmäki 73010022	Grave E/1950	EM	KM 12690:126	SIK003	Scapula
Salo (Halikko)	Rikalanmäki 73010022	Grave V/1950	EM	KM 12690:345	SIK004	Femur
Salo (Halikko)	Rikalanmäki 73010022	Grave Ö/1950	EM	KM 12690:430	SIK005	Radius
Salo (Halikko)	Rikalanmäki 73010022	Grave 2/1953	EM	KM 13298:26	SIK006	Femur
Salo (Halikko)	Rikalanmäki 73010022	Grave 7/1953	EM	KM 13298:145	SIK007	Tibia
Sauvo	Korvala 738010025	Grave 2/1996	RP	KM 29710:20	SAU001.A	Radius
Sauvo	Korvala 738010025	Grave 1/1996	RP	KM 29710:4	SAU002.A	Radius
Turku	Virusmäki 853010014	Inhumation	LIA-EM	KM 6659:73	TUV001.A	Femur
Uusikaarlepyy	Helgobacken	Cairn	BA?	KM 9952	HGB001.A	Tooth unspecified
Valkeakoski	Kiiliä 908010002	Grave 2/1935	LIA-EM	KM 10201:9	VAK001	Mandible
Valkeakoski	Kiiliä 908010002	Grave 1/1913	LIA-EM	KM 6370:206	VAK003	Pars petrosa
Valkeakoski	Muuntajanmäki 908010029	Grave 1/1990	LIA-EM	KM 26079:329	VLM001	Tooth unspecified
Vöyri	Sandbacka-Låg-peld 944010029	Cairn	RP-MiP	KM 7589:10	VLN005.A	Humerus
Ceded Karelia, Sakkola	Lapinlahti, Naskalinmäki	Inhumation	EM-M	KM 7291:31	SA1001.A	Cranium
Russian Karelia, Vitele	Pirdoila	Grave 4/1943	EM-M	KM 11367:57	VIT001.A	Ulna
Russian Karelia, Vitele	Pirdoila	Grave 1/1943	EM-M	KM 11367:18	VIT002.A	Metatarsus

was recovered from the sample (MK2007) taken from one of these human teeth.

We have also sampled individuals from the Late Iron Age (c. 700–1100 CE) multiple burials at Eura Luistari, which Lehtosalo-Hilander (2000: 156) has linked to a possible epidemic. However, no usable DNA - human or pathogen - was recovered from these remains. If pathogen DNA were preserved, Lehtosalo-Hilander's hypothesis could be explored more thoroughly (c.f. Margaryan et al. 2018; Spyrou et al. 2019).

Inhumation burials dating to the Roman Period (c. 1–400 CE) have been of particular importance in the history of Finnish archaeology. In the early 20th century, they were seen as a key to understanding the origins of the Finnish population. The burials were interpreted as evidence of the "first Finns" coming into Finland from the south (Hackman 1905), and the finds from Raasepori Kroggårdsmalmen tarand graves featured prominently in these narratives during the later decades (see, e.g., Asplund 2008: 201-202; Jansson 2011: 124). Recent research has refined these interpretations, and it is now known that the genomes of modern Finns are a mixture of immigrants from different time periods, and that people have arrived in the Finnish region from many directions over the millennia (Salmela 2025). The tarand graves have been associated with movements of Proto-Finnic-speaking groups rather than ethnic "Finns" over the Baltic Sea (e.g, Lang 2020: 278 - 281). The later excavated tarand graves at Sauvo Korvala and chronologically comparable sites at Porvoo Pikku Linnamäki and Nakkila Penttala, are also archaeologically significant, as they contribute to the broader image of the Roman Period in Finland. Unfortunately, no usable DNA has been obtained from any of these burials.

IS POOR SKELETAL PRESERVATION AN ISSUE?

In Finland, the environmental conditions present a challenge for the scientific analyses of archaeological human remains. The characteristically acidic soils accelerate the decomposition of unburnt bone, often leaving little to no recoverable skeletal material (Moilanen 2021: 31–32; Taavitsainen 1997: 53). From the Stone Age, when inhumation was practised, only small fragments of teeth and enamel typically survive (Ahola et al. 2016). During the Bronze Age (c. 1500–500 BCE), cremation became the dominant burial custom and remained so until the Late Iron Age (around 1000 CE). As cremation destroys DNA (Hansen 2017), most burials from this long period are currently unsuitable for genetic studies. A few notable exceptions exist, such as the water burial of Leväluhta (c. 400–600 CE) in Western Finland (Lamnidis et al. 2018), where the exceptionally good preservation of human remains is attributed to the waterlogged conditions, and a limited number of Early Iron Age (c. 500 BCE–400 CE) cairns and tarand graves, from which some unburned skeletal elements have survived. Some of the samples in our dataset could even originate from incomplete cremations, as they come from find contexts where cremated bones were also present (for example, Kokemäki Leikkimäki, Kuopio Kuusikkolahdenniemi, Pori Leppänen, and Uusikaarlepyy Helgobacken).

Inhumation burials began to increase from the Merovingian Period (c. 600–800 CE) and Viking Age (c. 800–1050 CE) onward in South-Western Finland, and in other regions by the Early Medieval period (c. 1050–1250 CE) (Hiekkanen 2010). The Early Medieval inhumation burials generally represent the oldest broadly available skeletal material for scientific analyses in Finland, although the preservation varies greatly even within a single site (Fig. 3). For example, at the Valkeakoski Toppolanmäki cemetery, grave 3/1937 contained a well-preserved skeleton buried without grave-goods or a coffin, whereas the adjacent grave 2/1936 contained a completely decomposed individual with only a phalanx preserved inside a finger ring. (Moilanen 2021: 32). Interestingly, soil analysis from grave 3/1937 has revealed the presence of Sphagnum moss (Moilanen et al. 2022a), whose complex carbohydrates are known to inhibit microbial decomposition (Børsheim et al. 2001; Hájek et al. 2010). This highlights the fact that while soil acidity is a major factor in bone preservation, it is not the only one. Studies on taphonomy and human remains have shown that contextual variables

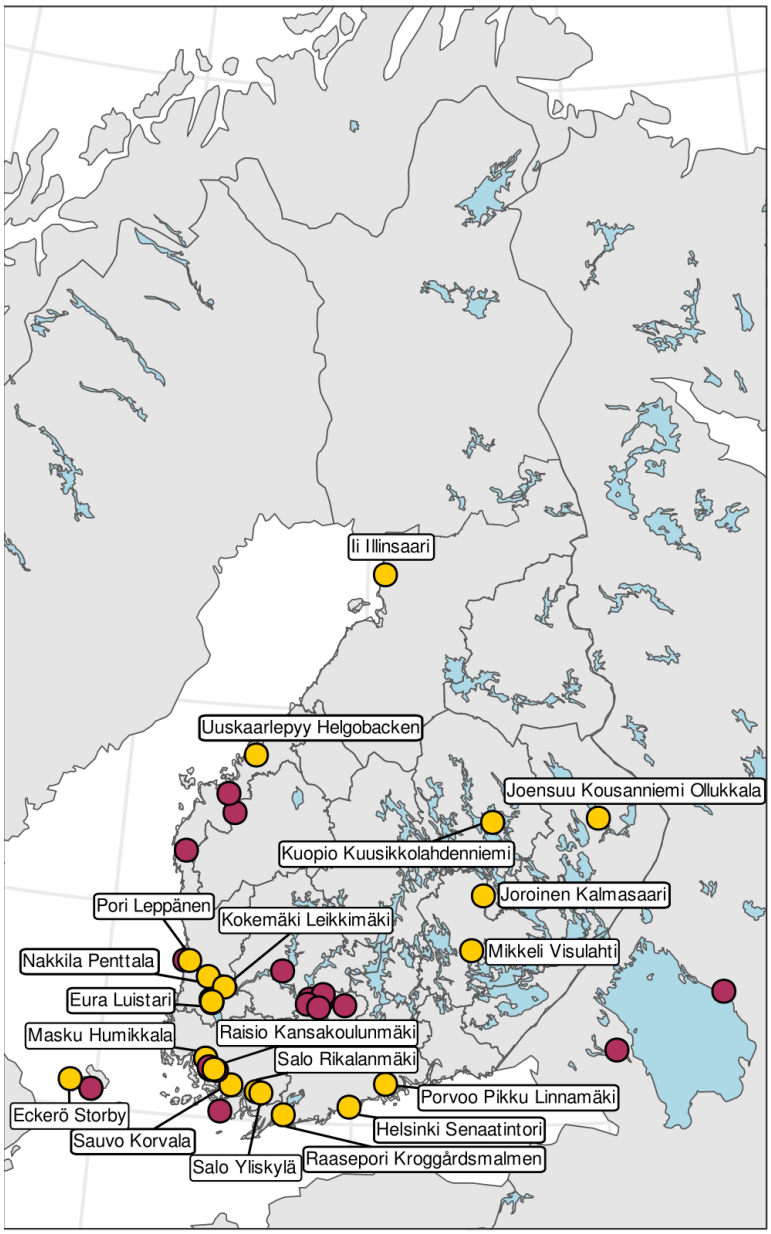

Figure 1. A map showing the locations of sites where unsuccessful samples are reported in this article. Sites discussed in the text are indicated with labels and highlighted with yellow markers, while other sites listed in Table 1 are marked in red.

and post-burial conditions can either slow down or accelerate the decay of organic material, including DNA. Among the most influential are pH, microstructure, and geochemistry of the soil, and microbial activity in the grave (Gordon & Buikstra 1981; Kibblewhite et al. 2015). Burial depth and the presence of containers, textiles or other organic materials can create microenvironments that further affect decomposition (Dent et al. 2004; Nord et al. 2005; Stojanowski et al. 2002; Emmons et al. 2020). Seasonal conditions at the time of burial also matter: colder and drier climates and weather conditions tend to delay decomposition (Mann et al. 1990; Roberts & Dabbs 2015), while elevated body temperature before death due to fever or sepsis may accelerate it (Hayman & Oxenham 2016).

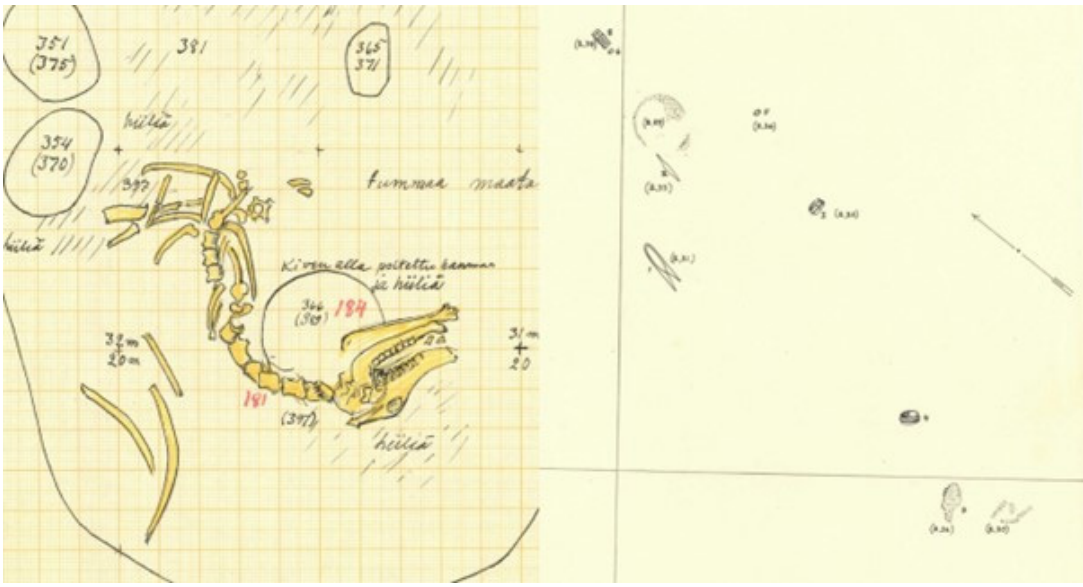

Figure 2. The "sacrificial ox of Mikkeli" on the left, and a Merovingian Period burial 7/1934 at the Köyliö Köyliönsaari (Kjulo Kjuloholm) cemetery on the right. In the documentation materials, the animal grave appears relatively well-preserved by Finnish standards (see also Taavitsainen 1990), while the Merovingian Period burial represents a more typical case in which only faint traces of decomposed bone are visible. Images: Jorma Leppäaho and Nils Cleve.

However, the visual condition of the bone does not automatically indicate whether or not DNA has been preserved. For example, at Tampere Vilusenharju, DNA has been successfully recovered from a tooth attached to a poorly preserved mandible, while no usable DNA was obtained from the petrous part of a well-preserved cranium in another grave (Nordfors et al. 2025a). It is noteworthy that even in geographical areas generally considered more favourable for bone preservation, such as certain parts of Åland, attempts to recover aDNA from relatively well-preserved remains have sometimes been unsuccessful.

PREDICTORS OF SUCCESSFUL DNA RECOVERY

Because our model treated DNA recovery as a binary outcome (success/failure), the results reflect the likelihood of obtaining any amount of analysable human DNA and do not take into account variation in data quality among successful samples. The strongest predictor for successful human DNA recovery was skeletal element: Petrous bones and teeth had substantially higher odds (OR: 65, 95% CI: 18–350 for petrous bones, OR: 6, 95% CI: 2–22 for teeth; Table S2) of successful human DNA recovery than other skeletal elements. These results are consistent with previous studies that have identified petrous bones and teeth as the most reliable sources of human aDNA (Damgaard et al. 2015, Hansen et al. 2017; Parker et al. 2020; Haarkötter et al. 2023). The odds ratios reported here may, however, be inflated by our sampling strategy: guided by previous studies, we selected petrous bones and teeth whenever they were available and only resorted to other skeletal elements when necessary. Thus, the extremely poor DNA preservation in elements other than petrous bones and teeth in our dataset may partly reflect the overall poor preservation of these burials.

In our model, sample age had a noticeable effect on DNA recovery: older samples were less likely to yield usable DNA. This is in line with DNA decay over time. In our dataset, library build had little effect on DNA recovery: single-stranded libraries showed a slight trend toward a

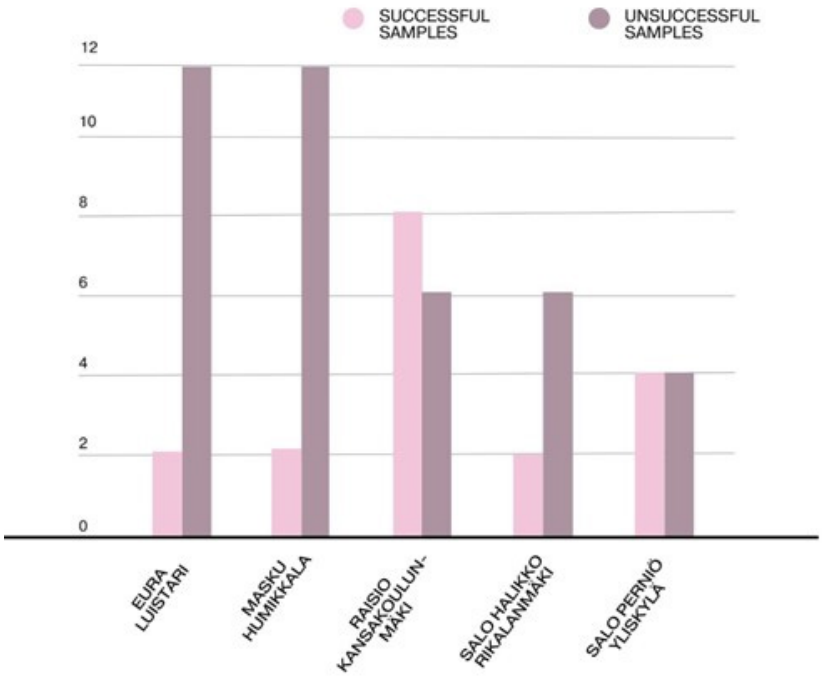

Figure 3. Number of unsuccessful and successful aDNA samples from selected Late Iron Age and Early Medieval sites in southwestern Finland. The outcomes present the variability of DNA preservation even within sites.

higher success rate, but this difference was not statistically significant. Notably, random site-specific factors accounted for approximately one-third of the variance in success rates, highlighting the role of depositional and environmental conditions in DNA preservation.

SAMPLING OUTCOMES BY SKELETAL ELEMENTS

The choice of skeletal element is widely recognised as one of the most critical factors in successful aDNA recovery. As stated above, the petrous part of the temporal bone is consistently identified as the most reliable source of endogenous aDNA, followed by dental root cementum. More recently, auditory ossicles have also shown potential despite their small size (Sirak et al. 2020). As noted above, our results support the previous findings (Fig. 4–6). By contrast, none of our samples taken from phalanges yielded usable DNA. Calcani, tali, and long bones have performed well in some previous studies (Emmons et al. 2020; Galob et al. 2024), but we have had no success with these bones. This likely reflects the overall poor preservation of Finnish burials, as we have only sampled these skeletal elements when no other elements have been available.

Some of the failed samples in our dataset (Table 1, SI) come from extremely poorly preserved inhumation burials, where skeletal material has survived only in association with metal objects (Fig. 7). These examples include arm and finger bones preserved inside arm and finger rings (e.g., Eura Käräjämäki-Osmanmäki, Luistari, and Pappilanmäki, Porvoo Pikkulinnamäki, Karjaa Kroggårdsmalmen, Sauvo Korvala). None of these samples have yielded human DNA.

The forensic study by Emmons et al. (2020) found that DNA preservation varies between different bones within the same individual and even within the same bone. Our dataset provides some support for this observation. For example, a humerus from grave 2 at Ii Illinsaari (sample ILS003 in Table 1) did not yield human DNA, whereas a tooth taken from the same individual

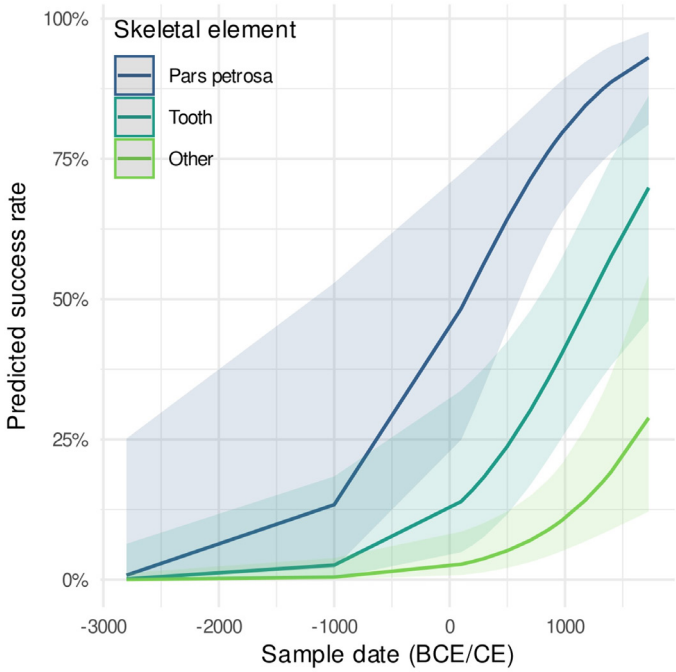

Figure 4. Predicted success rates of human DNA recovery for petrous bones, teeth, and other skeletal elements over a range of sample ages based on a generalised linear mixed model. Predicted probabilities are averaged over sites and library types; probabilities for a specific site or library type would be lower, particularly at older ages.

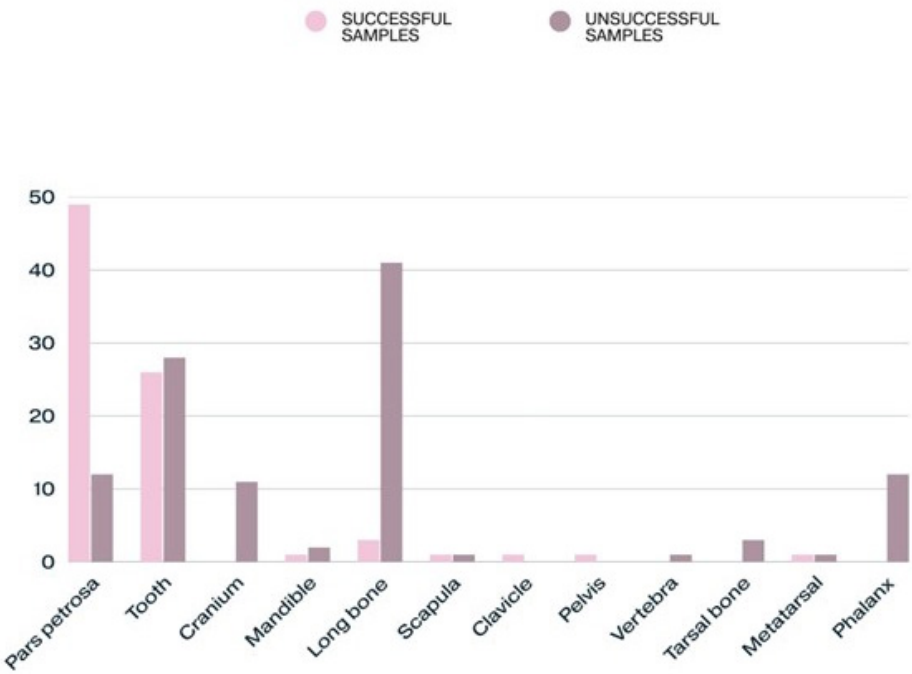

Figure 5. The sampled skeletal elements confirm findings from previous studies: the petrous part of the temporal bone is the most reliable element for DNA recovery. Samples from crania, phalanges, vertebrae and tarsal bones did not yield any DNA.

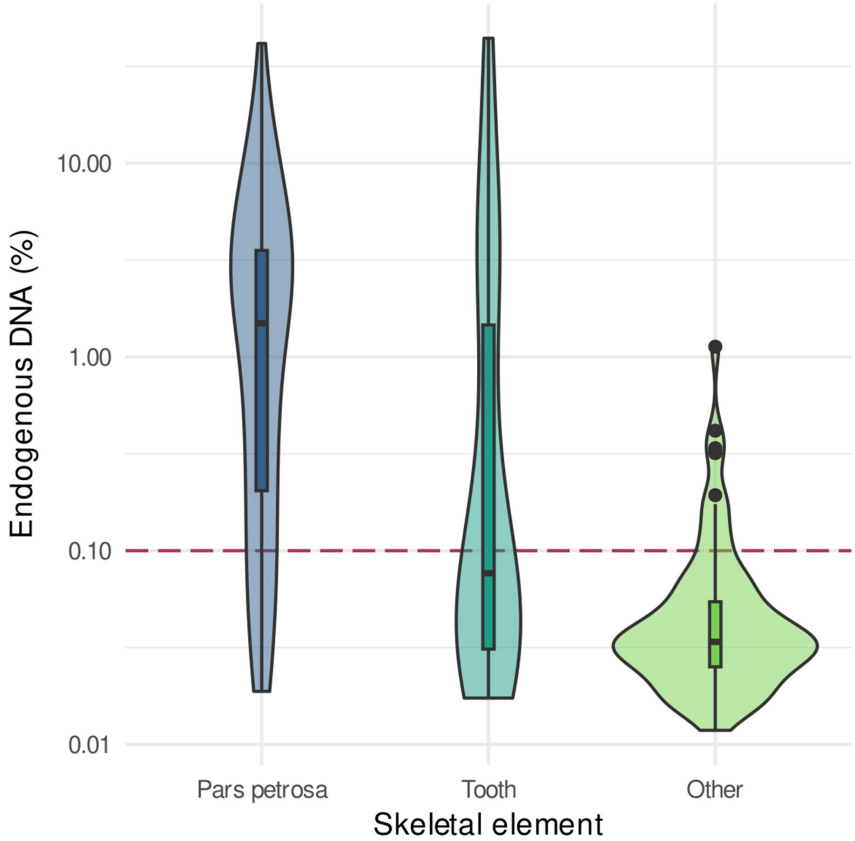

Figure 6. Endogenous DNA in different skeletal elements. Violin and box plots show the distribution of endogenous DNA percentage in pars petrosa, teeth, and other skeletal elements. The dashed line shows a common cut-off of endogenous DNA; samples with lower endogenous DNA are usually considered too poorly preserved to analyse further. The y-axis is on a log10 scale.

did. However, there are several examples in our dataset where sampling different bones from the same individual or burial context did not improve the results. For example, two different molars of an individual from grave 12/2014 at Illinsaari did not yield human DNA. Both a femur (RK3003) and a tooth (RK3004) from the same grave at Raisio Kansakoulunmäki did not yield usable human DNA. Similarly, two separate phalanges (MEL001) and a tooth (MEL003) from Eckerö Storby, Åland – all three possibly belonging to the same individual – were sampled without success. The same applies to the "Eura matron", from whom both *pars petrosa* and a tooth were sampled, but neither yielded DNA. Thus, occasionally, DNA has not been preserved even in the anatomically most favourable elements (Fig. 8).

TEMPORAL VARIATION

Based on archaeological contexts, some of the oldest remains from mainland Finland in our dataset are thought to derive from Bronze Age cremations (Table 1, SI), although the possibility of later secondary burials should also be considered. Several samples have been taken from bones deriving from Early Iron Age contexts, such as Roman and Migration Period (c. 1–600 CE) inhumation burials. These remains come from various burial types, and they represent some of the oldest Iron Age inhumations in Finland, but the success rates have been fairly low (Table 2). To date, only two attempts to recover DNA from Merovingian Period inhumation burials (c. 600–800 CE) in Finland have

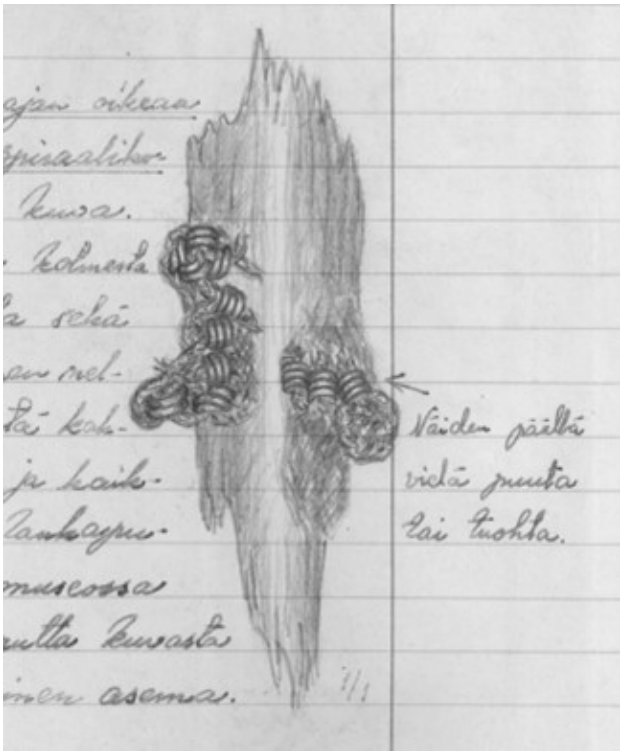

Figure 7. A drawing of bronze spirals and a bone fragment preserved beneath them in grave 2/1965 at Eura Yli-Nuoranne. Sample YLI001 was taken from the bone. In many Finnish cases, these kinds of fragments may be the only surviving bone material in an Iron Age grave. In unfurnished burials, the preservation may be even worse, although this varies even within sites. Image: Object catalogue KM 16950, Pirkko-Liisa Lehtosalo-Hilander.

Figure 8. DNA is not always well preserved even in anatomically favourable elements. Examples of sampled skeletal elements that did not yield DNA. Top row: petrous parts of the temporal bone from Eura Luistari (LUI034 and LUI033) and Nakkila Penttala (NAP001, on the right). Bottom row: a tooth from Helsinki Senaatintori (HKI006) and a talus from Salo (Perniö) Yliskylä (PYL005). Photos: K. Majander (LUI034, LUI033, NAP001, HKI006) and N.-J. Saari (PYL005).

Table 2. Samples from the Early Iron Age had a lower success rate compared to the Late Iron Age and Early Medieval samples, and the highest success rates were seen in the youngest samples. However, the chronologically younger samples, which generally yield more DNA may also have spent less time in museum storage, as the excavations of post-medieval sites in Finland have only become relatively common since the 1980s and 1990s.

Dating	–500 BCE	Early Iron Age (500 BCE–700 CE)	Late Iron Age (700–1100 CE)	Early Medieval (1100–1250 CE)	Medieval and Post-Medieval (1250 CE –)
Successful samples	-	9	10	50	13
Unsuccessful samples	5	19	7	40	5
Success rate %	0%	32.1%	58.8%	55.6%	72.2%

been successful.[1] This is reflected in our GLMM model, which shows a rather rapid drop in the predicted DNA recovery rate with time. However, even though DNA degrades progressively over time, there is substantial variation in DNA preservation among samples with similar chronological age (Thomas 1993: 4). Notably, even though none of the samples from the Early Iron Age tarand graves have yielded DNA, some contemporaneous samples from coastal cairns, such as Raahe Tervakangas and Vöyri Latjineliden, have produced usable data which is now under analysis for forthcoming publications. These differences are likely influenced more by regional and local preservation conditions, as well as the sampled skeletal element, than by the age of the remains.

Some previous studies have even reported better success on older samples compared to younger samples (Leney 2006; Tourunen & Niemi 2011: 35–36). The same has been observed at Pälkäne Rauniokirkko, where some 13th-century samples produced usable DNA, whereas one post-medieval burial did not (Nordfors et al. 2025a). Our dataset also includes other post-medieval cases in which no usable DNA was recovered from the samples (for example, Helsinki Senaatintori, Joroinen Kalmasaari, or the Orthodox cemetery at Joensuu Kousanniemi Ollukkala). The sampled skeletal elements from Senaatintori and Kalmasaari were teeth, suggesting that the lack of DNA preservation in these particular cases is strongly affected by burial-specific factors.

FUTURE PROSPECTS

Researchers and collection managers are frequently faced with the question of whether to sample human remains now or preserve the material until new analytical techniques are available. Because future methodological breakthroughs – much like those seen in the rapid development of aDNA research – cannot be predicted, careful preservation and curation of human remains are essential for future research. However, waiting is not always the best option, because DNA decay does not stop when the archaeological material is excavated and moved into a museum collection. Previous studies have shown that DNA may be better preserved in recently excavated materials (Eriksen et al. 2025; Nordfors et al. 2025a). In our dataset, long-term storage may have contributed to DNA degradation in some of the failed samples, as many of them were excavated decades ago, and some over a century ago (e.g., Appelgren-Kivalo 1907 [the description of excavation finds from Perniö in 1893], Ailio 1912; Pälsi 1925; Hackman 1930). However, some samples still yielded usable DNA despite having been curated in museum collections for over 130 years (e.g., KM 2487 and KM 2503, accessioned in 1887). This issue has received relatively little attention in aDNA studies, but it nevertheless raises questions about long-term preservation environments in museums. Given the broad scientific and cultural value of human remains, attention to storage conditions and practices is crucial for ensuring their value for the future.

In most cases, it is unlikely that the same unsuccessful samples presented here would yield usable aDNA in the future without significant methodological advances. The primary issue is not technical, but biological: When an organism dies, its DNA begins to degrade into increasingly shorter fragments until it is entirely gone. This degradation is driven by a range of taphonomic and environmental factors. Understanding these factors more precisely may require further research, which could be essential for reviewing sampling strategies in the future.

Our analyses have measured the preservation of human DNA, and although it likely reflects the overall DNA preservation in the sample, it remains theoretically possible that pathogen DNA could have survived even if human DNA has not. However, screening for ancient pathogen DNA can also be recommended, as it can provide information on the prevalence and impact of past diseases, while helping to clarify the circumstances and motives behind certain burial practices. Particularly in the cases of double or mass burials, it is generally advisable to sample more than one individual, if not all, as this would allow for the investigation of kinship relations and potential shared causes of death among the buried, provided DNA preservation is adequate (c.f. Haak et al. 2008; Schroeder et al. 2019).

In cases where DNA preservation is poor, valuable information can still be obtained with other methods. For example, paleoproteomics offers a promising alternative for aDNA analysis by providing information on the health and biological sex of the individual (Hendy 2021; Warinner et al. 2022). Likewise, isotopic analyses can illuminate aspects of past diets and mobility even for individuals whose DNA has not been preserved. For example, the teeth of the "Eura matron" have been successfully analysed with isotopic methods (Danielisová et al. 2025) despite unsuccessful DNA extraction. As analytical techniques continue to evolve, the range of information that can be derived from previously unsuccessfully sampled materials expands. This progress broadens the ways in which we can study human lives in the past and reduces reliance on a single methodological approach. In most cases, combining multiple lines of evidence can be the most fruitful way to carry out research on the same material, as different methods offer access to different types of information and can compensate for each other's limitations.

CONCLUSIONS

This study highlights the anatomical, temporal and environmental factors affecting ancient human DNA preservation in archaeological remains found in Finland. Despite the challenging preservation conditions caused by acidic soils, high microbial activity, and frequent cremation practices, usable aDNA has been recovered from various contexts. Our results reaffirm that the petrous part of the temporal bone remains the most reliable skeletal element for aDNA studies, followed by teeth, and that changes of DNA preservation in human remains decrease over time. Our examples also show that DNA survival in individual sites or burials can be highly unpredictable, and macroscopically well-preserved bone does not always correlate with molecular preservation. Temporal and regional patterns in DNA preservation were also observed. Chronologically younger samples, particularly from the Medieval and Post-Medieval periods, had higher success rates than earlier material, but these patterns may also reflect shorter museum storage times. Notably, some Early Iron Age coastal cairns produced usable DNA, whereas all tarand grave samples failed, suggesting that local conditions or burial practices may play a greater role than burial chronology alone. Given the irreversible nature of destructive sampling and the uncertainty of future technological advances, it is essential to balance research needs with the careful curation of human remains. Continued documentation, transparency, and publication of both successful and failed results will support more informed decision-making and promote responsible use of archaeological resources.

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Endnotes

1 Additionally, DNA has been successfully obtained from the Migration and Merovingian-Period site of Levänluhta, where unburned individuals were deposited in water (Lamnidis et al. 2018; Översti et al. 2019).

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KAROL – AN INTERDISCIPLINARY RESEARCH PROJECT ON THE SKULL COLLECTION RETURNED FROM THE KAROLINSKA INSTITUTE IN SWEDEN TO FINLAND

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INTRODUCTION

In August 2024, 82 human skulls were returned to Finland from Sweden, where they had been kept in the anatomical collections of the Karolinska Institute since the 19th century. The remains were returned to Pälkäne, because approximately half of them (42 individuals) had originally been collected from the old church of Pälkäne (Fig. 1) during Gustaf Retzius's fieldwork in 1873 (Retzius 1878; Ruohonen 2021). Local stakeholders had expressed a strong wish for the prompt reburial of the remains, and this was scheduled only two weeks after the return of the remains. As a result, all documentation and sampling of the material had to be carried out within a narrow timeframe. Members of

our team performed the documentation and sampling of the skulls at the new church of Pälkäne (Fig. 2).

The documentation process included osteological examination, the production of 3D models of the intact skulls and CT scans of four mummified individuals at Tampere University Hospital. From all returned skulls, samples for ancient DNA (aDNA) and protein analyses, radiocarbon dating, and stable isotope studies were collected. In addition, a few small soil and seed samples from the ear canals were retrieved, as well as entomological material preserved on the crania. Together, the varied sample types provide a foundation for research of the assemblage.

Our research project is scheduled to continue at least through 2027, and it is currently funded by the Kone Foundation and the Pirkanmaa Regional Fund of the Finnish Cultural Foundation. Further support has also come from the Kuopio Museum for the analysis of soil samples from North Savo (Kirkinen 2025), and from the Museum Centre Vapriikki for fieldwork, CT scans of mummified individuals, and textile analyses of the silk bonnets preserved on two of the Pälkäne skulls (Kirjavainen, in press). The headgear was not reburied but instead catalogued in the collections of the Historical Museums of Tampere, which include nationally significant textiles and have specialized textile conservation facilities (Honkasalo 2013: 9).

THE HUMAN REMAINS

In addition to the 42 individuals from Pälkäne, the assemblage also included other skulls collected during Retzius's expedition in 1873. These skulls originate from Pielavesi (7 individuals), Rautalampi (3 individuals), and Eno (2 individuals), and one additional skull was later sent to Retzius from Pielavesi by Rudolf

Figure 1. The old church of Pälkäne was abandoned in the 1830s after the completion of the new church. The stone church dates to the late 15th - early 16th century CE, but earlier wooden churches preceded it on the same site. The oldest excavated burials from the site date to the 13th century CE. Individuals of higher social status were buried inside the church, and 19th-century accounts report that after Retzius's visit, several graves within the building stood open and some of the deceased were missing their heads (Koukkula 1972: 566). Photo: U. Nordfors.

Jack (Ruohonen 2021; Åhrén et al. 2024). These remains were later transferred from Pälkäne to their respective home parishes for reburial.

Approximately one-third of the skulls (26 individuals) originated from the anatomical collections of the University of Helsinki from where they had been donated to Sweden during the 19th century. Many of these skulls bear traces of autopsy, and most of them belonged to prisoners of the Sveaborg (Viapori) fortress. Four of these individuals, originating from Ulvila, Pori, Kiuruvesi, and Helsinki, are known by name (Åhrén et al. 2024). The assemblage also includes individuals whose geographical origins are known but whose identities remain uncertain. This group includes a man convicted of homicide from Häme, as well as individuals from Saarijärvi, Paltamo, Turku, Halikko, and broadly Karelia.

Our project also received an additional named individual from Rovaniemi. This skull had originally been donated from the Sveaborg prison to the anatomical collections of the University of Helsinki, where it had remained for more than a century without ever being transferred to Sweden. In the early 2000s, the skull had been sent to the Sámi Museum Siida as part of the repatriation of Sámi ancestral remains. It was later determined that the individual did not belong to the Sámi population, and the skull was redirected to Rovaniemi for burial. There, the living relatives of the individual expressed a wish for further analyses, which could be carried out in our project.

AIMS OF THE RESEARCH PROJECT

Determining the appropriate burial places for individuals whose origins remain unknown

The decision issued by the Finnish Ministry of Education and Culture (VN/36221/2023-OKM-1) stipulates that the human remains returned from the Karolinska Institute must be

Figure 2. In 2024, we worked in a field laboratory set up in the new church of Pälkäne, where we documented the skulls and collected samples prior to the reburial. Protective suits were worn throughout the process, even though the material had been handled for more than a century. With this choice, we sought to avoid introducing additional contamination from ourselves. Photo: S. Säilynoja, Museum Centre Vapriikki.

reburied. However, the assemblage includes 17 individuals whose geographical origins remain unknown. Establishing the most probable home region of these individuals is essential for ensuring their legal rights and equal treatment, so that they can be reburied in a location that aligns with their historical and cultural context. To achieve this, we combine scientific analyses with historical research, which together provide a robust framework for assessing provenance.

Ancient DNA analyses, particularly approaches that leverage DNA segments identical by descent (IBD), play a central role in this task. IBD analysis examines long segments of DNA that two or more individuals share through recent common ancestry (Ringbauer et al. 2017). Historically, Finns have usually found their partners and remained in the region where they were born, which appears as localized patterns of IBD sharing: on average, individuals originating from the same region share more IBD segments with each other than with individuals from other regions (Kerminen et al. 2017; Martin et al. 2018). By comparing each unidentified individual's genome to a large dataset of present-day genomes from Finland, we can assess the geographic distribution of their shared IBD segments within the country. The spatial clustering of these segments often gives the most precise estimate of an individual's genetic origins (see Nordfors et al. 2025). Our project is conducted at the University of Turku within the Centre of Excellence for Human Diversity through Contacts (HuDi-Con), which provides us access to the extensive genomic dataset of present-day Finns maintained by the Finnish Institute for Health and Welfare (THL).

However, genetic ancestry does not automatically reveal where an individual resided during their lifetime. Therefore, isotopic analysis, particularly the study of strontium isotope ratios($^{87}Sr/^{86}Sr$), complements the DNA data by providing an independent perspective on geographic background. Strontium isotope ratios reflect regional geological variation and are incorporated into human tissues through food and drinking water (Bentley 2006; Lahtinen et al. 2020). Because teeth mineralise at different stages from early childhood to early adulthood, strontium values from multiple teeth can reveal residential mobility and changes in place of residence during formative life phases. Our sampling strategy therefore includes several dental elements, allowing for a comprehensive reconstruction of individual life histories. This approach helps determine whether the deceased were born and raised in the same locality and identifies the geological region from which they most likely originated.

Historical sources are also used in determining the likely origins of the unidentified individuals. Although the Karolinska Institute's archival records were largely destroyed in a 19th-century fire (Åhren et al. 2024), a surviving shelf inventory lists several Finnish localities from which skulls had been obtained. Additional place names are listed in Retzius's *Finska kranier* publication (Retzius 1878). By comparing the results of genetic and isotopic analyses with the localities mentioned in these historical documents, we can narrow down the range of plausible places of origin and better assess the likelihood of particular geographical associations.

The diverse life histories of individuals

Our aim is to reconstruct multidimensional life histories for all 83 individuals by combining evidence from various biological, historical, and archaeological sources. For an anatomical collection such as this, highlighting the human histories behind the remains is important, given that the original collectors operated within their contemporary scientific norms that afforded limited attention to the life histories or social identities of the individuals involved. New approaches allow the material to be reintegrated into its historical contexts and the individuals to be understood once again as lived members of their communities and societies.

We perform radiocarbon dating (Uusitalo et al. 2022) of individuals recovered from the various burial grounds around Finland as well as from the church of Pälkäne. These analyses provide chronological information about both the periods during which the sites were in use and the lifespans of the individuals themselves. At Pälkäne, radiocarbon dating is particularly crucial, as the church served as a burial place from the 13th to the 19th century (Nordfors et al. 2025) and remains recovered from the same site

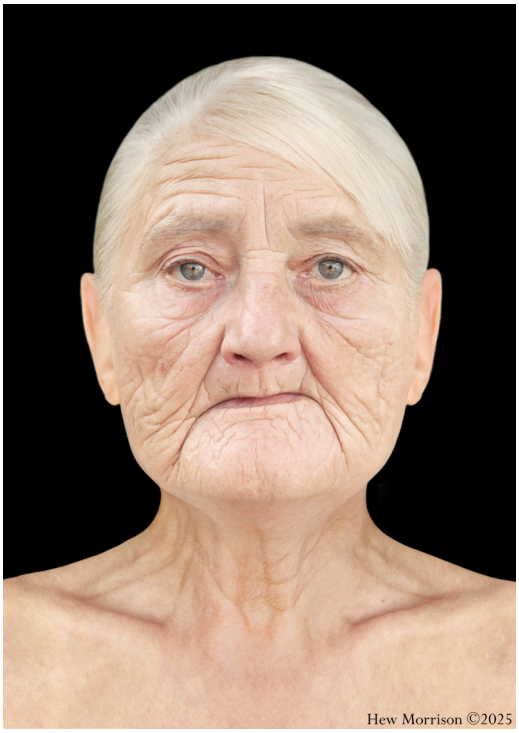

Figure 3. A facial reconstruction of an elderly female V168. The reconstruction work is done by a forensic artist, and it forms part of our broader effort to reconstruct the life histories of these individuals. Picture: H. Morrison.

may therefore originate from markedly different centuries. However, because several individuals likely date to the historical period - during which the atmospheric radiocarbon content has greatly varied - their radiocarbon results may produce broad ranges spanning through the past few centuries. To obtain greater precision, we analyze multiple tissue types, such as teeth and different cranial bones, from the same individual to leverage their different years of formation.

Various other methods allow us to investigate the lifestyle, health, and disease of these individuals. Osteological analysis provides information on health conditions and behaviours even when only the skull is preserved. Teeth and bones may show for example signs of nutritional deficiencies in childhood or adulthood, infections, or healed trauma, and dental wear can indicate certain habits, for example, pipe smoking (e.g., Scott 2018).

Using DNA and proteomic methods, we also investigate pathogens and oral microbiome, whose species provide indicators of general health (Warinner et al. 2015; Hendy 2021). The presence of bacteria, viruses, and protozoa offers evidence of living conditions, interpersonal contacts (infectious diseases), environment, and hygiene. Parasites transmitted via animals or between humans further illuminate hygiene practices and the role of domestic animals in daily life (Søe et al. 2018; Tams et al. 2018). We also examine whether individuals carried chromosomal aneuploidies, such as Down syndrome (Rohrlach et al. 2024), Finnish Disease Heritage mutations (Norio 2003), or other known disease-associated variants. Ancient DNA also reveals inherited phenotypic traits such as hair and eye colour, which can be incorporated into facial reconstructions that we produce for public engagement (Fig. 3).

Stable isotope analysis of carbon and nitrogen contributes information on the diets (Makarewicz & Sealy 2015) and can also reveal breastfeeding histories by indicating the age at which individuals transitioned from breast milk to solid foods (Jay 2009). Dietary reconstruction is further refined through palaeoproteomics, as dental calculus can preserve proteins from milk, fish, and meat (Warinner et al. 2022).

Historical records form a key component of our contextual work. Parish registers provide information on the life courses of named individuals and their families, while court records at district, appellate, and senate levels contain details about the imprisonment and deaths of those held at Sveaborg. The burial sites excavated by Retzius in 1873 are reviewed using published accounts, the expedition diary found in 2022, and supplementary oral histories and local folklore. Together, these sources allow us to situate each find within its broader historical and archaeological setting, both as community members in life and as burial sites in a landscape. (See Fig.4 for a visual representation of KAROL's multidisciplinary workflow.)

New knowledge on historical communities and populations

A total of 42 skulls in the assemblage originate from Pälkäne, where we have previously analysed DNA data from 21 individuals recovered from archaeological excavations.

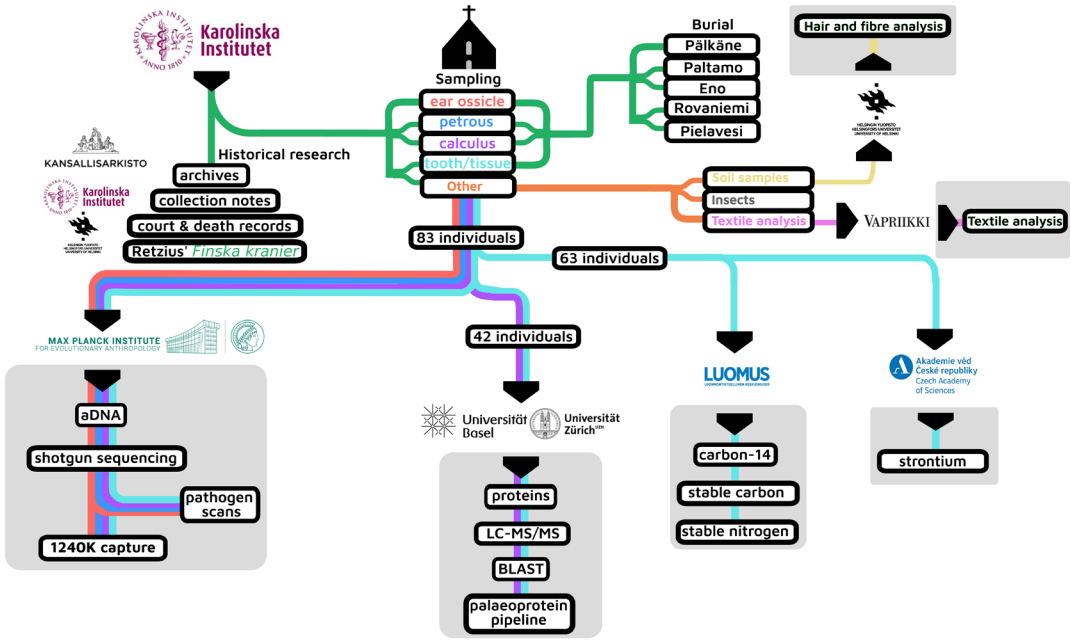

Figure 4. Tubemap diagram of the KAROL project's multidisciplinary workflow. The movement of skulls, ear ossicles, petrous bones, calculus samples, and tooth/other tissue is indicated by green, orange, blue, purple, and cyan tubes, respectively. The institutions where laboratory work is conducted are indicated by their respective logos. Image: S. Peltola & R.J. O'Sullivan.

Together, these 63 individuals constitute one of the largest bioarchaeological datasets from the same locality currently available from Finland. This assemblage allows us to assess the size of the Pälkäne population, patterns of kinship and mobility, and the community's connections to surrounding regions. In addition to the Pälkäne individuals, the collection includes people with known places of origin from Pielavesi, Rautalampi, Kiuruvesi, Paltamo, and Eno (15 individuals in total). These are especially important because central and eastern Finland have been underrepresented in Finnish ancient DNA research. Their inclusion enables more detailed investigation of the long-recognised east–west genetic, linguistic, and cultural divide in Finland (Salmela et al. 2008; Kerminen et al. 2017). This divide is also reflected in the distribution of common disease-associated genetic variants: for instance, the higher incidence of coronary artery disease in Eastern Finland is at least partially driven by genetic factors (Kerminen et al. 2019). Moreover, many rare disorders belonging to the Finnish Disease Heritage (FDH) (Norio 2003) have geographically restricted distributions in eastern Finland, shaped by post-medieval migration and demographic bottlenecks.

Taken together, the dataset offers an exceptional cross-section of Finland's population in the historical period, including individuals from varied social and geographic backgrounds. Prisoners, for example, represent a very different social milieu from the Pälkäne parishioners buried within the church, enabling concrete comparisons of differences in everyday conditions and lived experiences. The material also opens perspectives onto broader historical phenomena, including 19th-century prison life and potential regional differences in dietary practices.

A concrete connection to the present and descendants

The return of the collection has prompted many people to wonder whether the skulls might include their distant relatives. It is likely that many of these individuals have living direct descendants or more distant kin today. Although genetic relatedness cannot always be verified beyond six generations using DNA alone (Salmela 2025),

surviving genetic connections may nevertheless provide a valuable resource for those engaged in genetic genealogy. For many, exploring such connections carries emotional significance, as it links them to past generations, places of origin, and broader familial networks.

In accordance with standard practice in ancient DNA research, the genomic data generated by the project will generally be made publicly available alongside the scientific publications, which in principle enables comparison with raw data generated by commercial genetic testing services. In practice, however, such comparisons require technical expertise. Commercial platforms also often utilise published ancient DNA data in their services, but they lack methodological transparency and often offer only vague and sometimes misleading interpretations of genetic relationships between ancient and living individuals. Furthermore, these international services rarely, if ever, take into account population-specific factors, such as the high background relatedness of the Finnish population. Owing to the high level of public interest, our project will seek to develop an accessible tool that allows users of commercial DNA tests to compare their data with that of the individuals we have analysed, providing scientifically informed insights into their own genetic roots.

Ethical considerations

A central priority of the project is to ensure that all individuals in the assemblage are treated with dignity and respect. This commitment raises a number of complex ethical questions that have no straightforward answers: where should the boundary of privacy be drawn for people who can no longer speak for themselves; how can we avoid exploiting the human histories represented by the remains; and to what extent do we have the right to act as interpreters of these individuals' lives (see, e.g., Tarlow 2006; 2012; Henderson & Cardoso 2018; Squires et al. 2022)? Our material also includes individuals who are known by name, as well as prisoners, so we must exercise careful judgement before releasing data and results (see Tarlow 2023).

Also, questions surrounding facial reconstruction (see e.g., Johnson 2016, Møllegaard 2025) require considerations, and we continually assess whether producing reconstructions, especially of prisoners, can be justified ethically. Within the project, we also consider the ethical implications of preserving 3D models of the skulls. Questions arise regarding where such digital representations should be archived, who should have access to them, and for what purposes they may be used (see Smith & Hirst 2019; Bohling 2025).

An additional ethical consideration concerns the possibility that some skulls may not originate from Finland. The histories of old anatomical collections may be fragmentary, and misattributions are not uncommon (Harmon 2018; Carmack et al. 2024). Should any individual prove to be non-Finnish, we would reassess our responsibilities accordingly, including questions of appropriate consultation and potential return.

We place particular emphasis on transparency and responsibility throughout the research process. The progress of the project and the reasoning behind our decisions are communicated openly on the project's Facebook page (https://www.facebook.com/profile.php?id=61570485848880) and in public lectures. We also collaborate closely with Museum Centre Vapriikki and several regional museums, which may incorporate our findings into their exhibition work. Ultimately, our aim is to advance scientific knowledge while ensuring that our work honors the deceased and contributes to a respectful and meaningful engagement with the past.

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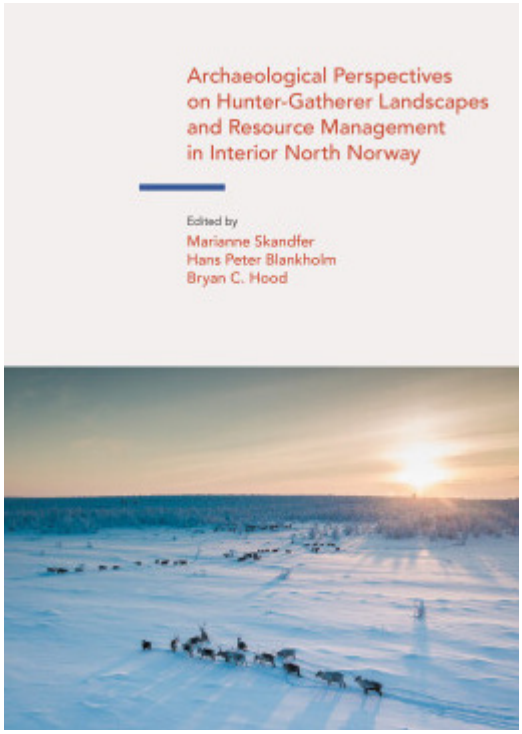
Marianne Skandfer, Peter Blankholm, Bryan C. Hood (eds.) *Archaeological Perspectives on Hunter-Gatherer Landscapes and Resource Management in Interior North Norway*. **Equinox, 2024. ISBN 9781781798171. 822 pp.**



'If archaeologists working outside of northern Fennoscandia were asked what they associate with northern Norway and its adjacent regions they might mention Vikings and ethnographic Sami reindeer herding, but they would probably be hard pressed to come up with any other images.' This sentiment, undoubtedly true, starts off a new book in two parts. The stated raison d'être of the book is 'the first synthesis of northern Norwegian inland archaeology'. But in doing so the authors accomplish much more. All in all, the result is a synthesis of the past of the northern parts of what is now Sápmi, the homeland of the indigenous Sámi people. The region is also known from the southern perspective as Northern Lapland.

The timespan of the book ranges from the last glaciation some 12,000 years ago to about 500 years ago, when the European states began to expand to the region. The book is the main offspring of the 'Landscape and Resource Management (LARM)' -project, conducted by archaeologists of the Arctic University in Troms, Norway, in 2009–2013. The project and consequently the book presents plenty of new field work results collated in relation to earlier research in and around the north Norway inland.

Contrasting with your basic project report, this book contains a good measure of background and theory, which elevates the book into a more widely relevant and applicable work. The inland of Arctic Norway is skillfully contextualized around questions that define much of the Northern Fennoscandian past, related to issues such as the post-glacial pioneer settlement, the dwelling boom of the 4th millennium BCE, and the process leading to the emergence of reindeer pastoralism after 500 CE. The wide yet source critical application of ethnographic analogies lays the groundwork for robust and convincing archaeological interpretation.

Each chapter is separately authored, and Bryan Hood, who lead-authors 11 chapters, has apparently done most of the writing, with editing primarily conducted by Marianne Skandfer, who also lead-authors three chapters. Hans Peter Blankholm, contributing to several other chapters, lead-authors three chapters, with two additional chapters contributed by Asgeir Svestad and Helge Irgens Høeg. Each chapter is structured as a semi-independent contribution, which leads to plenty of repetition. This is not necessarily a flaw, as presumably most readers will be interested in specific chapter-based topics. Reading the book from start to finish, though, brings with it many deja vú moments, but such repetition is rarely harmful to the reader especially in a work as broad as this.

Chapter 1, the introduction, establishes the main concepts and questions related to the region, as well as an initial overview of its cultural history. In general, culture history acts as linchpin for the book, providing much of the

narrative framework. The next chapter, Chapter 2, 'Research History Overview', provides a thorough background of the development of archaeology in the region from its emergent days in the early 1800s to the 1970s. Also included are the earlier accounts ranging from the Fennoi of Greco-Roman geographical sources to the Sámi of the early ethnographies. The narrative familiarizes the reader to the research history through archaeology pioneers such as Gutorm Gjessing to Ørnulv Vorren and Povl Simonsen and some of their field work, which we return to in Chapter 7.

Chapter 3, 'Concepts and Methods', involves a deconstruction of terminology mostly in relation to landscape, such as ’hunting’, ’herding’, and ’domestication’, as well as the all-important ’transition’ between them. Such terms are revealed as conceptual packages that hide within them a range of generalizations and assumptions from elsewhere. The chapter also includes a near-dictionary of Sápmi cultural remains, such as different kinds of hearths and dwellings. So if you’re ever wondering, for instance, what a *bearpmet árran* is, look to this chapter for the answer. Furthermore, the book’s preoccupation with representativeness pretty much begins with this chapter, highlighting the authors’ intent on providing a methodical review of the region’s archaeology for future application.

The theoretical framework, or many modular elements of it, is presented in Chapter 4, 'Reflections on Living in Landscapes', where the authors introduce what they label ’practice ecology’. This seemingly original concept ’implies a perspective based on actors making decisions within a context structured by cultural values on the one hand, and ecological constraints and opportunities on the other.’ Especially in the context of the book, the approach seems quite sensical. As the book title states, the framework focuses mostly on resource management within the context of landscape relations, applying critically elements of Traditional Ecological Knowledge. Related to the landscape are human relations to places and animals, as well as place names, mostly describing past activities in the location.

Chapter 5 reflects on the physical parameters of the landscape, both its geology, including sourcing of different stone materials, and its biosphere, i.e. general plant life, and animals most relevant to humans that are mammals, fish, and birds. Chapter 6 takes the environmental conditions further by introducing paleoenvironmental reconstructions with emphasis on climate and dominant tree species during the last 10,000 years. These chapters provide deep background for the upcoming materiality sections, starting with Chapter 7, which details the archaeological research history in Interior Finnmark and Troms. This chapter is the heftiest with 67 pages. Here is where the book begins to read like a catalogue. This is usually the case when presenting large assemblages of sites and related excavations with a concise narrative. This is especially the case here, since the research history contains enough details pertaining to specific excavated areas and their finds that the reader does get the impression that we are truly talking here about all the excavations in the region. The next 200 pages, chapters 8–11, detail the results of the project’s own field work with a division into chapters by region. These chapters may not be for everyone but are understandably essential for future research, especially since the following chapters further extrapolate from these results.

Chapter 12 offers an overview of the 121 known Stone Age house pits found in the interior regions. Included are all the pertinent typological analyses as well as a general discussion that reflects upon the contemporaneity of nearby dwellings and their reuse, with the conclusion that the house pit assemblage of the interior seems to follow its own unique logic relative to the coast, where the number of known house pits amounts to thousands. Chapter 13 has a similar take on trapping pits found in the interior. The interior North Sápmi is characterized by vast hunting pit systems with nearly 10,000 pits in total. This gives archaeologists much to work with, and the related questions are pretty much the same wherever hunting pit systems are found, giving extra weight for the chapter in the context of Fennoscandian trapping pit use.

Chapter 14, 'Settlement models for Stone Age Interior Finnmark', studies ‘subsistence-settlement variability in relation to long-term environmental changes’, using mainly

the (food-)resources of the inland as the foundation for settlement modeling. Chapter 15 is a speculative account of two different stages of reindeer herding, conceptualized as 'hunting-embedded herding' and 'large-scale pastoralism', leaning mostly on historical sources and ethnographic deduction. Chapter 16 is where human-reindeer relations and the herding-pastoralism question are studied through the archaeological evidence, whilst keeping in mind the more hypothetical discussions of the previous chapter. Wrapping the analytical chapters is Chapter 17, which studies the 1553–1752 Swedish taxation and population records of Interior Finnmark. The related statistical analysis forms a chronological bookend, a 'what came after' of the earlier chapters.

The narrative, but not the theoretical framework, is largely culture historical, with each chapter exhibiting a chronological structure from past to present. This works mostly well, although reading several chapters in succession brings about temporal vertigo. Some chapters are even structured with looping chronologies, which repeat from old to new from different perspectives, a structure that might have worked better composed differently.

Figures are mostly excellent, especially site and artefact photographs, but also the many topographical maps. Distribution maps from excavations allow the reader to really sink their teeth into specific sites. There are some quirks. Among them is Figure 10.4 which is a full page section drawing, rotated 90 degrees, that is 6 meters wide and apparently 5 cm deep depicted in the same scale, cutting the white page in half from top to bottom with a 2 mm wide snaking pole, which leaves you wondering, whether this is a joke by the arctic archaeologists to contrast the oft-nonexistent cultural layers of the north with thick stratigraphies of almost anywhere else in the world. If so, kudos on a job well done.

Another puzzling decision is to have Chapter 18, 'Pollen-analytical investigations in Finnmark', as the final chapter preceding the concluding section. In the chapter, the different terminological constructs of agriculture in relation to cultivation and anywhere in between are not discussed or defined. Instead, all anthropochores (plants that spread alongside humans) are interpreted as evidence of agriculture. This chapter presents evidence of such agriculture in the interior North Norway as early as 1600 BCE. The main evidence seems to be the pollen of broadleaf and ribwort plantain, known medicinal plants, which is intriguing in its own right. The reader is left wondering whether the placement of the chapter to the very end was caused by scheduling issues, with most of the book already written and the conflicting interpretations of agricultural activities around and after 1600 BCE surfacing too late in the game to be properly embedded. The concluding Chapter 19 does not comment on Chapter 18 at all, with the agricultural interpretation pre-emptively dismissed in Chapter 14[1], making it seem all the more an outlier. It serves to raise more questions than answers. Unintentionally this only strengthens a sense of unresolvedness of the region's archaeological narrative, which in the opinion of the book's authors, despite their best efforts, remains exactly that: unresolved.

The two-part book is not exactly leisurely in its narrative and can at times be a heavy read, but as a near-total synthesis of the current state of archaeology of the region it is immensely readable and should be considered required reading for all archaeologists venturing into the geographic or thematic territory. The book not only offers new insight into a former *terra incognita* but also synthesizes a lot of widely pertinent ethnography and clarifying research history, making a service for the general field.

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Endnotes

1 p. 575: 'A pollen core from the highlands just north of Kárášjohka/Karasjok contained Cerealia pollen dated to 1500 BC, which was interpreted as a potential indicator of cultivation (see Chapter 18, this volume). However, the location hardly seems suitable for cultigens. […] The problem, however, is whether it is possible to distinguish cultigen pollen from that of wild grasses […].'