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Preface

The present 7th volume of *the Monographs of the Archaeological Society of Finland* builds on presentations given at the XI Nordic Conference on the Application of Scientific Methods in Archaeology that took place in Helsinki, Finland, October 20th–23rd 2015. The meeting was arranged as a twin conference with the X Nordic Meeting on Stratigraphy, organized by the Archaeological Society of Finland, the Finnish Antiquarian Society, the Finnish Museum of Natural History (LUOMUS), the Finnish Heriatge Agency (the former National Board of Antiquities), the Society for Medieval Archaeology in Finland, and the University of Helsinki Department of Archaeology.

The joint themes of the twin conference included the Baltic Sea, Demography, diet and health, Geophysical prospection, and Current challenges for scientific dating methods. For SMIA XI papers concerning material studies – elemental analyses, dating methods, stable isotopes, geophysical prospection, osteology and paleopathology, ancient DNA, biological indicators, paleoclimate, paleodemography, and new methods and techniques, were also invited.

The papers in this volume are the harvest of the SMIA XI conference and cover a variety of the conference themes. It is not unwarranted to say that the present volume gives a representative cross-section of the methodological and topical issues at the center of scientific archaeology, not only in 2015, but also today. However, archaeology would not be archaeology without a look at the past. In this case, and in line with the multidisciplinary nature of SMIA, this look is not provided by an archaeologist, but instead by professor Högne Jungner, one of the founders and driving forces of the whole SMIA concept and the long time head of the University of Helsinki Radiocarbon Dating Laboratory (today the Laboratory of Chronology). Högne's retrospective look at the early years of SMIA forms the second part of the introductory section.

The rest of the volume is dedicated to peer-reviewed papers, the topics of which include a method of combining aDNA, stone tools, and computer modeling (Persson et al.), various analyses of pottery (Papakosta & Pesonen, Brorsson et al.), the analysis of chemical composition of soils (Kulkova et al.), identification and interpretation of osteological materials (Shaymuratova et al., Harlin et al.), geoarchaeology of building stones (Kinnunen & Seppänen), and microscopical analysis of perishable organic materials (Kirkinen et al.). Geographically the papers in this volume cover northeastern Europe; the focus in all papers is on material deriving from Fennoscandia, the Baltic countries or northwestern Russia. Chronologically they span from the earliest postglacial pioneer settlement ca. 11,000 years ago to premodern times.

Helsinki, April 2019

Kristiina Mannermaa, Mikael A. Manninen, Petro Pesonen, Liisa Seppänen

The early days of SMIA in perspective

HÖGNE JUNGNER

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When planning for the first Nordic Conference, the organizing committee, in the first circular wrote:

> *"In view of the large number of specialized technical methods now available for the study of archaeological problems, it is important that means be provided to improve contacts among archaeologists and specialists. Archaeologists must be made aware of new developments in the physical, chemical, and biological sciences applicable to their own field, and, of equal importance, of the limitations and uncertainties inherent in the methods.*
>
> *On the other hand, the specialists must be informed about the needs of the archaeologists in order to adapt their methods to the archaeological problems."*

This can well be compared to the very similar definition of the purpose of Scientific Methods in Archaeology in the circular inviting participants to the present meeting "The X Nordic Meeting on Stratigraphy & The XI Nordic Conference on the Application of Scientific Methods in Archaeology SMIA XI". So, what has changed? Clearly a lot.

The first initiative came mainly from us working in dating. The radiocarbon method had already produced a lot of data and the impact on chronology was obvious. At the same time, we learned more about calibration of radiocarbon dates and the need to correct for isotopic fractionation, hard water effect, etc. The accelerator technique was also developing and that suddenly opened up for new possibilities but also raised new requirements for sample selection and treatment. Originating with the March meetings at the Research Laboratory for Archaeology and the History of Art in Oxford, UK, the thermoluminescence method was brought to Denmark, and also to us in Helsinki.

It was a time of enthusiasm. But this can also be seen as an international trend. The field of archaeometry was introduced and International meetings were being held.A week after the second Nordic meeting in Helsingör, Denmark, the First International Conference on C14 and Archaeology was held in Groningen, the Netherlands. The French association for archaeometry: GMPCA (Groupe des Méthodes Pluridisciplinaires Contribuant à l'Archéologie) was founded in 1976, and it works to promote archaeometry in France and worldwide, while organising biannual conferences. On a wider inter-national scale, it should be mentioned that the already 41st International Symposium on Archaeometry (ISA) took place in May 15–21, 2016 in Kalamata, Greece.

Figure 1. Participants in the 3rd SMIA conference, held in 1984 in Mariehamn (Åland), gathered ready for an excursion to the Kastelholm Castle. A number of papers dealing with medieval archaeology at and around the castle were given at the conference. Photo: Högne Jungner.

One aim of the first SMIA conference was to discuss the potential Nordic co-operation on the development of thermoluminescence dating. The idea of a Nordic Laboratory for Thermoluminescence and other archaeometric methods had been under discussion with representatives of all the Nordic countries. The plans for the implementation of new techniques were well received, but most archaeologists felt that their needs would be better served by national laboratories working closely together. A few years later the Nordic Laboratory for Luminescence Dating was finally established and has today achieved a well-documented international status. A similar initiative was also discussed in 1982 regarding a Nordic cooperation in accelerator dating. Also in this case the establishment of separate national laboratories was preferred, and today there are accelerators for dating in all Nordic countries except Iceland.

At the second SMIA meeting held in Denmark, a number of papers on different dating methods, C14, thermoluminescence and dendrochronology, were presented. The accelerator technique was introduced, and as an example of the use of stable carbon isotopes, a paper showing the change in the diet of prehistoric humans in Denmark was given. In addition, papers on soil studies, magnetic prospection, neutron activation analysis and osteological studies, should be mentioned. Of interest were also the presentations of projects with combination of archaeometric methods such as: Helgeandsholmen in Stockholm, the town of Skien in Norway, and excavations at an Iron Age site in Salo in southwest Finland. A similar multi-disciplinary trend continued at the SMIA meetings that followed.

At our first Nordic meetings, we had many participants also from outside the Nordic countries. In that respect the Nordic meetings created wider contacts. An important role was played by the PACT group, in the beginning formed as an advisory group under the European Council. At that time, the financial support by Strasbourg and Brussels was not available as it is today, but some support for meetings and publication costs was possible to obtain. In fact, looking at the series of PACT publications, one can see that many volumes are related to Nordic activities.

Figure 2. Dr Galina Hutt (center) from the Institute of Geology, Tallinn, professor Garman Harbottle (right) from Brookhaven National Laboratory, New York, professor Joakim Donner (left) from Institute of Geology, Helsinki and Högne Jungner in a lively discussion at the reception of the 3rd SMIA meeting (Mariehamn, Åland).

Regarding the PACT activities, it should be mentioned that there was not only information transferred from more southern Europe to the northern countries. In fact, bioindicators like pollen and spores, which are widely used by northern archaeologists met a lot of interest down south. The cooperation between archaeologists and geologists has a long tradition in the Nordic countries. At that time, the discussion about recent climatic change was not that prevalent, but climate has always influenced environment and humans. This type of scientific activities leading to frequent visits to Strasbourg also provided for chances to learn about lobbying.

Digitalization has of course changed all experimental work, when compared to the situation in the early 70's. Online preparation methods and new detector systems make it possible to analyze new materials and much smaller samples at much higher throughput. Good examples are the accelerator technique applied to dating, and the modern analyzing methods for stable isotope studies. Advances in biochemistry brings fascinating possibilities to be applied in archaeology. Digitalization has also changed data handling while much more advanced statistical methods are available today. This can be compared with early data handling by calculators, letters by typewriters and snail mail.

This becomes particularly apparent when considering today´s possibilities provided by the internet, communication being very different when compared to the early days. When arranging the 3rd SMIA conference in 1984, I remember that all correspondence was based on typewriting and sending letters by mail. With more than 200 participants, it meant sending out and receiving a few hundred letters.

The Internet also in many ways strongly influences co-operation and research. Research groups, and even large consortia, can be brought together, and information and data can be exchanged without delay. The possibility to bring out new knowledge through open-access channels is developing rapidly. All this did not exist when the first proceedings from our Nordic meetings were published.

Archaeometry is a field where two cultures meet: science and humanities. That requires cooperation between researchers from many different fields. In his book "*Consilience: The Unity of Knowledge*", Edward O. Wilson discussed methods that have been used to unite science, and might be able to unite science with humanities. Wilson used the term "consilience" to describe the synthesis of knowledge from different specialized fields of human endeavor. The Finnish philosopher Georg Henrik von Wright in ”*Humanismen som livshållning och andra essayer*” suggests ”A common basis is the intelligent relationships to the subject we study”. It is important to show respect for each other's work.

Despite the almost unlimited possibilities that seem to appear through the digitalized world and artificial intelligence, we still as humans, need to come together at meetings like the SMIA XI, for open discussions and the exchange of ideas.

I therefore conclude by referring to the wisdom of Väinämöinen in the introduction of the Finnish epic poem Kalevala (Translated from Finnish by Keith Bosley):

The words unfreeze in my mouth
and the phrases are tumbling
upon my tongue they scramble
along my teeth they scatter.
Brother dear, little brother
fair one who grew up with me
start off now singing with me
begin reciting with me
since we have got together
since we have come from two ways!

We seldom get together
and meet each other
on these poor borders
the luckless lands of the North.
Let's strike hand to hand
fingers into finger-gaps
that we may sing some good things
set some of the best things forth
for those darling ones to hear
for those with a mind to know
among the youngsters rising
among the people growing –

Selected reading

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Articles

The hidden sources

Combining aDNA, stone tools, and computer modeling in the study of human colonization of Norway

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Abstract

A two-way colonization pattern has been observed for most terrestrial pioneer and boreal forest species in Norway after the last glacial period: One route from the south, and another from the east through northernmost Fennoscandia. It is generally accepted that these routes represent plant and animal populations spreading from separate glacial refugia, a pattern manifested by genetic differences. The traditional model of pioneer colonization of the Scandinavian peninsula, however, suggests only a southern route for the early human dispersal and only recently has this view started to change. Here we present the foundations for the Pioneers of North-Western Europe project (Museum of Cultural History, University of Oslo, Norway) that aims at clarifying the colonization patterns of the early post-glacial humans in north-western Europe by challenging and testing the views of unidirectional human dispersal. This is achieved by tracing the spread of distinct knowledge-intensive operational chains of stone tool technology and by comparing the results with independent ancient human DNA data.

Keywords: aDNA, mtDNA, lithic technology, bone technology, colonization, modeling

Introduction: Objectives of the project

The timing and tempo of ice sheet retreat in north-western Europe at the end of the last glacial cycle caused the main part of Fennoscandia to remain unsettled until the end of the cold Younger Dryas period ca. 9700 BC. During the following Preboreal, rapid climate changes signified improvements for settlement and facilitated human expansion into Scandinavia (Wygal & Heidenreich 2014; Bjerck 2008; Brinch Petersen 2009; Riede 2014). To determine where these pioneer colonizers of north-western Europe, and more specifically Norway, came

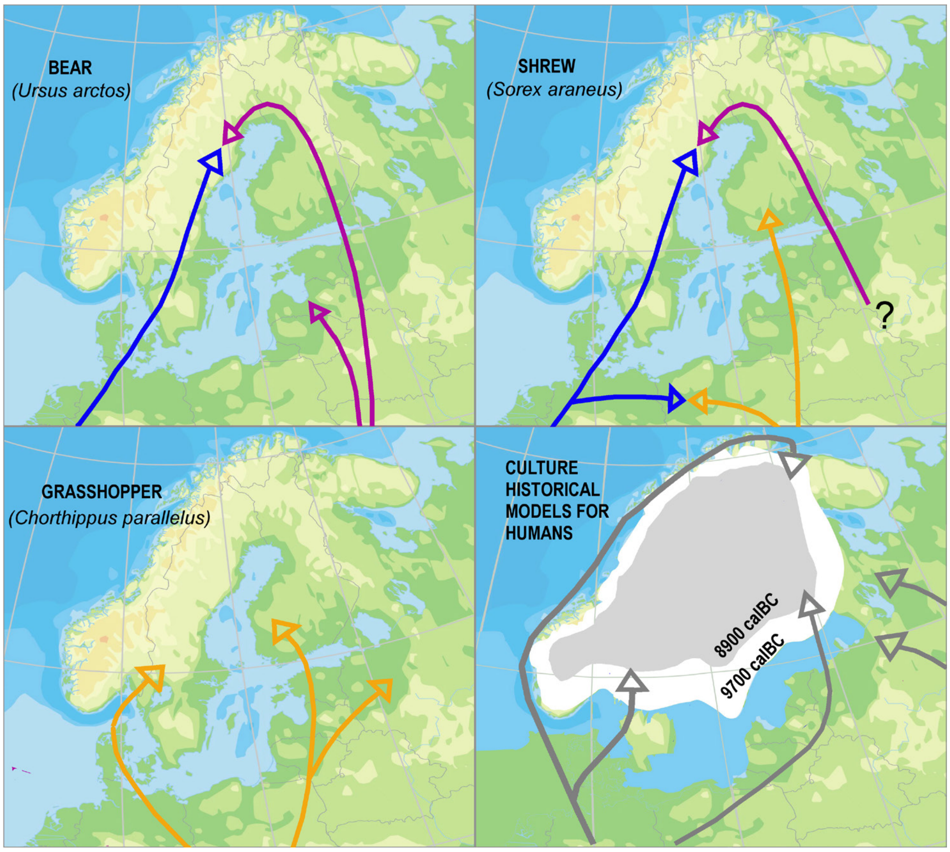


Figure 1. Examples of post-glacial colonization patterns of animal species into Scandinavia (modified from Hewitt 2001) and a schematic map indicating the extent of the Scandinavian Ice Sheet at 9700 BC and 8900 BC as well as different culture-historical models for human dispersal into Fennoscandia during ice sheet retreat. Coloured arrows in the colonization maps indicate genetic markers ascribed to different glacial refugia.

from, we will produce new data and evaluate the plausibility of different models of late- and post-glacial human dispersal in Europe.

It is well known that many animal species spread into Fennoscandia along two routes, a southern and an eastern (Figure 1), and from different Ice Age refugia in Eurasia (e.g., Hewitt 1999; 2001). Combined with new evidence of the spreading of knowledge and know-how into early post-glacial Norway from the east in form of technological concepts (Sørensen et al. 2013; Bergsvik & David 2015; Damlien 2016), this brings to the fore the question whether and to what extent a similar pattern can be detected for post-glacial human dispersal (Knutsson & Knutsson 2012; Kleppe 2014; Riede & Tallavaara 2014).

In the past few years, the methodology of ancient DNA (aDNA) research has gone forward in great leaps with the advent of next generation sequencing, while valuable insight into demographic processes have been gained from an increasing number of ancient individuals having their full genome sequenced (Slatkin & Racimo 2016). We aim to add more individuals from the region to this list and use the combined power of full genome and mitochondrial DNA (mtDNA) analysis.

Computer simulation will be used to evaluate different models of post-glacial pioneer settlement in north-western Europe. The outcome of the simulations will be compared with archaeological and genetic data. The genetic data consists of aDNA results achieved in our project as well as other relevant genetic information. The archaeological source material consists of lithic and bone artefacts and the results of technological analyses conducted using these artefacts. In this paper we present the background for the study and an overview of the research in progress.

Background for the study of late- and post-glacial colonization of north-western Europe

Archaeology

From the location of the ecologically most favourable areas in Europe during the Late Glacial Maximum, it has for long been assumed that analogously to that of other species, also human presence was restricted to two major refugia in Europe during the Late Glacial Maximum (LGM) (e.g., Indreko 1948; Dolukhanov 1979; 1998; Zvelebil 2001). According to the most favoured view today, the Franco-Cantabrian "Mediterranean province", connected to less-well-defined regions along the Mediterranean, provided a refugium for the human population of Atlantic Europe, while the "Periglacial province", located on the East-European Plain, is argued to have provided favourable circumstances for Upper Palaeolithic communities in central and eastern Europe. From these refugia hunter-gatherer groups are then assumed to have colonized the north-west European lowland and the Russian Plain when these areas gradually became habitable (e.g., Jochim 1987; Soffer 1987; Straus 1991; Gamble et al. 2005; 2006; Brewster et al. 2014).

At the end of the last glacial period, humans started to colonize those areas that were gradually exposed during the retreat of the Scandinavian ice sheet. In north-western Europe this expansion is usually seen as connected to reindeer hunting. It is believed that reindeer hunters changed their foraging ranges accordingly as the ice sheet became smaller and the favourable environment for reindeer moved north. Typological reasoning and radiocarbon dating are used to link earlier south-west and central European Paleolithic cultures to the terminal Paleolithic Ahrensburg culture, suggesting that the earliest immigrants in north-western Europe had their roots in the Upper Paleolithic population of south-western Europe (Price 2015: 32-56, and references within) and later possibly Doggerland, i.e., the now submerged North Sea continent (Ballin & Bjerck 2015; Bjerck 1995). In this case the dispersal of these groups towards north would have started ca. 14,000 BC, the first settlement of southern Scandinavia ca. 12,500 BC, and while interrupted by the Younger Dryas, the pioneer colonization would finally have reached Norway ca. 9500 BC. For the final phases of the process, many researchers today argue that the Ahrensburg culture underwent a transformation from reindeer hunting to hunting of sea mammals in West-Sweden (e.g., Schmitt 2015 and references within). This formed a new type of "coastal epi-Ahrensburgian" that expanded further north along the Norwegian coast.

Researchers in Norway have for long acknowledged that the earliest known sites in the area of present day Norway to a large extent are located along former sea shores. It was therefore considered likely that people came in boats rather than over land bridges. However, at the same time it was also noted that there was a possibility for pioneer colonizers to have arrived from the east into the northernmost part of the country (Bøe & Nummedal 1936; Gjessing 1945; Odner 1966; Hagen 1977).

The alternatives presented for the origin and ways of arrival of the first postglacial inhabitants of Norway can be summarized as: 1) directly by boat from Doggerland or southern Scandinavia, 2) moving along the coast from Doggerland, 3) from Eastern Europe via Lapland, 4) following reindeer from south-western Europe through land bridges, and 5) reindeer hunters transforming into maritime hunters in West-Sweden and continuing northward by boat. All of these alternatives have shown to be hard to prove due to taphonomic reasons. In Norway the preservation of bone assemblages is poor at the earliest sites, and therefore practically nothing is known about the animal species targeted by the Early Mesolithic groups, nor is there knowledge on possible boats, fishing, or sea mammal hunting in Doggerland during Late Paleolithic time, due to a ca. 100 meters rise of sea level since the end of the Ice Age (Fairbanks 1989).

East of Norway, in Finland, the roots of pioneer population were earlier often traced to central Europe, or both east and southwest of the country, on the basis of culture-historical reasoning, typology, and an assumed connection to central European Late Paleolithic cultures, such as the Swiderian and Federmesser (e.g., Luho 1956; Siiriäinen 1984; Nuñez 1987; Matiskainen 1996; Schulz 1998). However, many culture-historical assumptions have been later shown not to hold. For example, the view that the Early Mesolithic quartz industry in Finland had types from the central European Federmesser, as well as other Paleolithic technocomplexes, was shown to result from a misclassification of quartz fragments (Siiräinen 1981) and the idea that so-called post-Swiderian points descended from Swiderian points has also been rejected, while the post-Swiderian is nowadays considered unrelated to the Swiderian (see, e.g., Zhilin 2005). Since the mid-1980's the "post-Swiderian" finds in Finland are associated with Early Mesolithic cultures in Estonia and Russia, namely Kunda and Butovo (see, e.g., Zhilin 2003; Hertell & Manninen 2006; Rankama & Kankaanpää 2011; Hertell & Tallavaara 2011 and references therein).

In recent years the study of technological trajectories and the transmission of technology have begun to replace typological studies. Stone tool and related bone tool technologies at the Paleolithic/Mesolithic transition seem to divide northern Europe, broadly speaking, into two Early Mesolithic traditions: an eastern tradition characterized by so-called post-Swiderian eastern technologies found, for example, in north-western Russia and Fennoscandia, and a western tradition, in Norway characterized by the Ahrensburgian and epi-Ahrensburgian (Hensbacka/Fosna/Komsa) technology (Figure 2).

aDNA

Tracing kinship back to past generations seems an ideal way to detect the origin of people. If, for example, the origin of the Mesolithic groups in Fennoscandia could be traced, it would be possible to detect correlations between genetic and cultural evolution. However, before the end of the 20th century, methods for reconstructing human ancestry did not exist. Craniology and then mainly measurement of skull proportions (Coon 1939, and references therein), and later also blood-groups (Mourant 1983) were investigated, but the results never become widely accepted. When research on mtDNA was launched in the mid-1980's, a more reliable method became available (Cann et al. 1984). In Europe, mtDNA studies have focused on Ice Age refugia as the main explaining factor for the distribution of mtDNA types, or haplogroups, among present-day Europeans. A classic example can be found in Bryan Sykes' book *Seven daughters of Eve* (2001) in which the origins of most mitochondrial groups among present day Europeans are pinpointed to different refugia in southern Europe. However, a series of alternative scenarios have been presented. For example, in 2012 Maria Pala and co-workers wrote that:

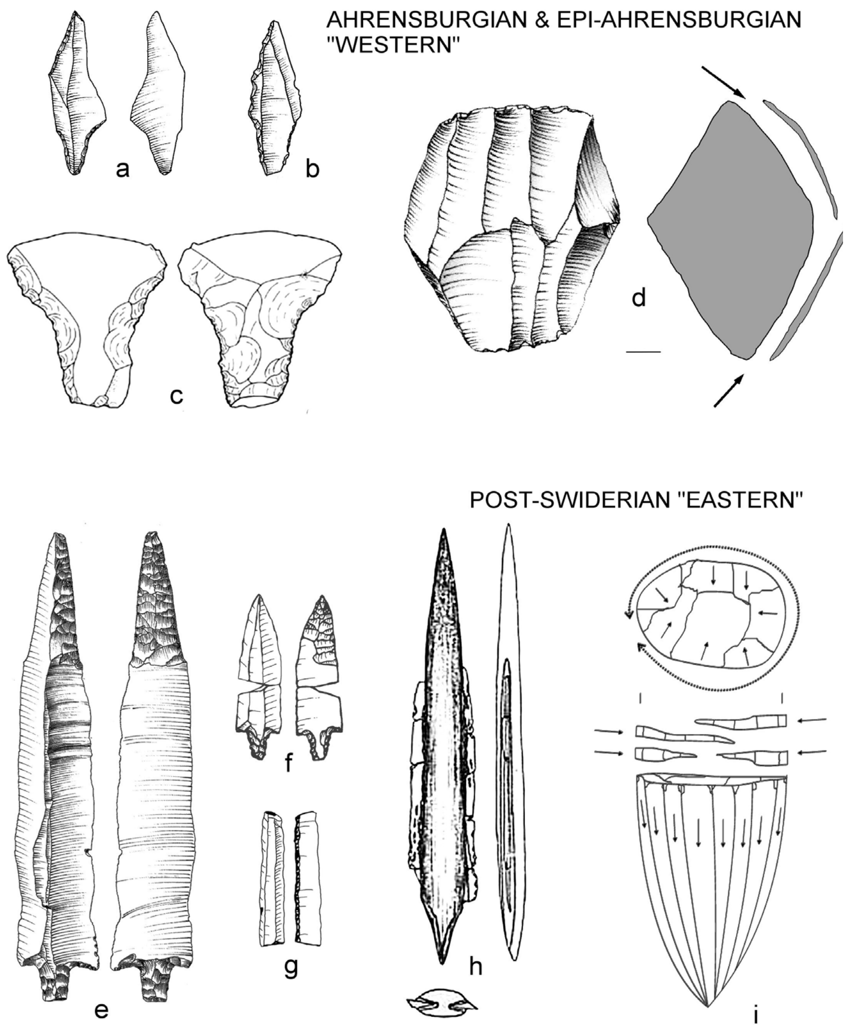


Figure 2. Examples of typical "western" Ahrensburgian and epi-Ahrensburgian tools and blade core reduction practices and "eastern" post-Swiderian counterparts: a) Ahrensburgian point (after Taute 1968 in Ballin & Saville 2003: Fig. 5); b) single- edged tanged point (after Ballin & Bjerck 2015: Fig. 6); c) early Hensbacka flake axe (after Schmitt & Svedhage 2015: Fig. 3); d) opposed platform soft hammer blade core (after Andersson & Knarrström 1999 in Fuglestvedt 2012: Fig. 4); e) post-Swiderian Pulli point (after Manninen & Hertell 2011); f) post-Swiderian arrowhead (after Takala 2004); g) flint insert for slotted bone tool (after Jussila et al. 2012); h) slotted point with flint inserts (after Skakun et al. 2011); "eastern" conical blade core with facetted platform (after Sørensen et al. 2013: Fig. 1). Not to scale. Redrawn from original drawings.

> *"Human populations, along with those of many other species, are thought to have contracted into a number of refuge areas at the height of the last Ice Age. European populations are believed to be, to a large extent, the descendants of the inhabitants of these refugia, and some extant mtDNA lineages can be traced to refugia in Franco-Cantabria (haplogroups H1, H3, V, and U5b1), the Italian Peninsula (U5b3), and the East European Plain (U4 and U5a)."*
> (Pala et al. 2012:1).

These studies draw conclusions about past events in population history from the genes of present-day Europeans. The genetic data that are utilized in the studies include the distribution of mtDNA haplogroups, the amount of genetic variation within each of these groups, and the difference within their area of distribution. Dating is carried out by the "molecular clock", assuming a constant rate of mutations. These studies were also tried for uncovering the origin of the pioneer colonizers of Fennoscandia (Riede et al. 2013). The problem is, however, that there has not been an independent way to verify the achieved results. Today, studies of ancient DNA (aDNA) can yield the needed independent test and are therefore a major step forward.

The first attempts to extract DNA from old remains and use them for genetic study were carried out in the 1980's. The first breakthrough in aDNA studies was the application of PCR technology (polymerase chain reaction) on ancient remains

(Pääbo & Wilson 1988). The interest in ancient DNA increased rapidly after the first study of DNA in old bones (Hagelberg et al. 1989). The "amplification" of old DNA with PCR seemed like the perfect method for studying all kinds of archaeological problems related to genetics (Ross 1992). A multitude of aDNA projects were launched. Among these were studies on the introduction of agriculture in Europe, which addressed the question of population continuity over the introduction of agriculture, and therefore included DNA from Mesolithic individuals.

Ancient DNA seemed ideal for solving the old dispute about the role of immigrant farmers in the spread of agriculture, but results turned out to be much harder to obtain than initially hoped. This was because of contamination by recent human DNA which turned out to be a major problem. A breakthrough came in 2009 when Barbara Bramanti and co-workers published a study of twenty individuals representing the pre-Neolithic European population (Bramanti et al. 2009). The study showed strong dominance of the U5 and U4 groups of mtDNA in the Mesolithic samples while these haplogroups were absent in the early farmer population investigated in the same study. The agriculturalists represented groups H, HV, K, T, W, and N1a, which did not appear among the studied hunter-gatherers.

The two populations, Mesolithic and Early Neolithic, showed very little overlap in their mtDNA group composition (Figure 3), which strongly indicates that the Early Neolithic population in Central Europe did not descend from the local Mesolithic population. Although methods for verifying the authenticity of the aDNA results were not available at the time, it is highly unlikely that contamination should lead to two populations showing such distinct grouping as Bramanti and co-workers found. That all Mesolithic samples were contaminated by present day individuals from the same haplogroups, while the Early Neolithic samples were not, or vice versa, is not probable. The mitochondrial group N1a also carries some importance in this respect, as it is rare among Europeans today. Therefore, it is not very likely that its high proportion among the studied Neolithic individuals in the Bramanti et al. (2009) study was the result of contamination.

At the moment, there are more than 140 Mesolithic individuals from Europe with their mtDNA type determined and the number is rapidly raising. Some of them are from old investigations and the authenticity of each and every result is not 100% secure. Despite this, there is a clear dominance of haplogroups U5, U4 and U2, which together constitute over 80% of the individuals (Figure 4). Because of their proportion and distribution among individuals living today, already before the aDNA studies, these three mitochondrial haplogroups were considered to have their origin in Europe (Soares et al. 2010). Considering the aDNA results, the strong presence of these haplogroups among Mesolithic Europeans can now be said to be confirmed.

A second breakthrough in aDNA research took place around 2010 when new sequencing methods came into use. These methods were first developed by a group led by Svante Pääbo working with the sequencing of the Neanderthal genome (Green et al. 2010). However, the group was surpassed by a new team led by Eske Willerslev in Copenhagen, starting later but using newer technology which helped to finish earlier and to be the first team to present a "total" ancient genome, in this case from a 4000 years old Greenlander (Rasmussen et al. 2010).

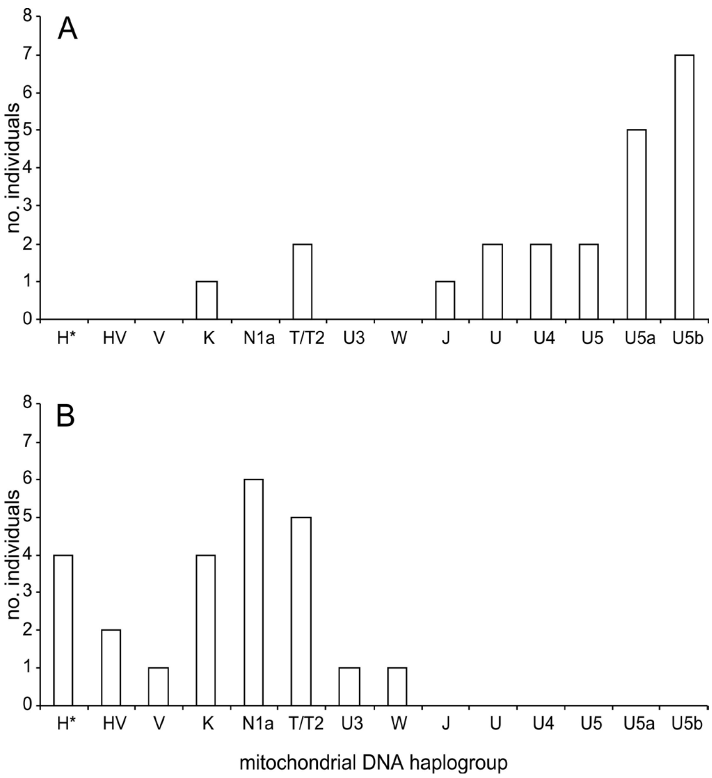


Figure 3. The number of individuals per mitochondrial DNA haplogroup in the Bramanti et al. (2009) study, the first successful aDNA study on Mesolithic samples. All studied individuals derive from European Stone Age contexts and are divided into two groups according to subsistence strategy: A) Hunter-Gatherers and B) Neolithic farmers. The farmer group consists of individuals from the Linearbandkeramik culture (the earliest Neolithic culture in central Europe) while the hunter-gatherers group is more heterogeneous and contains Mesolithic individuals together with individuals from "sub-Neolithic" cultures. Data from Bramanti et al. 2009: table 1.

The new methods enabled to greatly increase the number of DNA sequences from ancient samples and made it possible to investigate, not only the mitochondrial DNA sequences, but also the rest of the six billion base pairs that make up the human genome. For the first time it was also possible to confirm the authenticity of aDNA sequences, since characteristic damage typical for ancient DNA molecules can be used to distinguish them from modern contamination. As a result of these methodological improvements, we nowadays have access to genomic information from more than 80 Mesolithic individuals in Europe (Mathieson et al. 2017: Supplementary Table 1 lists 82 Meso-lithic individuals). The best preserved of these Mesolithic individuals has more than 50 times coverage of its total DNA sequence, which for the time being can be considered a very good result, although the average coverage for all Mesolithic individuals is much lower. The low coverage means that the Mesolithic individuals cannot be directly compared with each other gene by gene. Instead they are compared with living humans.

The results of such comparison can be presented in different ways. Of these, the PCA plot is considered the most illustrative. A number of such plots have been published in recent years, while the highest numbers of Mesolithic European individuals; 79, are presented in papers by Iain Mathieson et al. (2017:Fig. 1). A few details in this plot (Figure 5) are worth emphasizing here: 1) All Mesolithic individuals plot outside the genetic variation of present populations; 2) There seems to be structure in the distribution of the Mesolithic individuals in that three Russian individuals make up a group of their own in one end of the distribution while 11 individuals from southern and central Europe constitute an other group at the other end. Mesolithic individuals from Sweden, Ukraine, Latvia and the Iron Gates of the Danube River all fall in groups of their own, all placed in the plot between the first mentioned two; 3) Taken as a whole, the total genetic variation within the Mesolithic sample population is large. It is in the same range as the variation in the European population today.

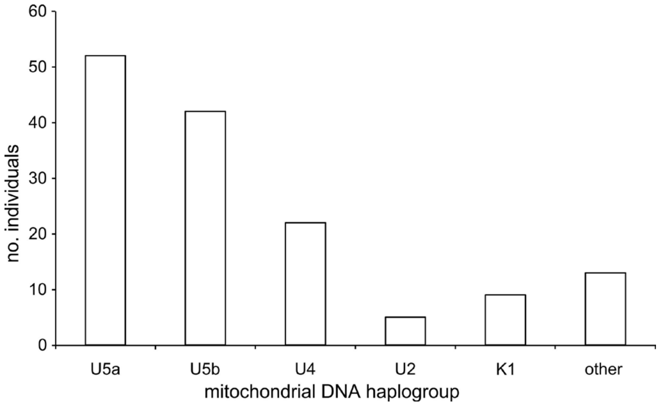


Figure 4. European Mesolithic individuals with information on mtDNA haplogroup (n=143) in June 2017.

Pioneers of Norway – the way forward

Archaeology

Although the spread of archaeologically detectable material culture traits and technology cannot be directly linked with population movement, it can be argued that changes in cultural traditions should usually be slow and that history explains a significant fraction of human behaviour (e.g., Boyd & Richerson 1985: 56–60; see also Pagel & Mace 2004; Shennan 2009), while rapid change is more probably a consequence of outside pressure, such as environmental crisis or demic diffusion. People acquire most of their skills by imitation and social interaction, and therefore language differences and hinders for movement, such as the Scandinavian Ice Sheet in the case of Pleistocene and early Holocene north-western Europe, and to smaller degree also the Baltic Sea basin and the Caledonian mountain range, consequently prompt cultural divergence that is self-reinforcing (Boyd & Richerson 2005: 379–396; Pagel & Mace 2004). The basis of the *chaîne opératoire* approach used in the study of pre-industrial technology can be tracked down to this same general notion. In this approach the *chaîne opératoire*, that is, an

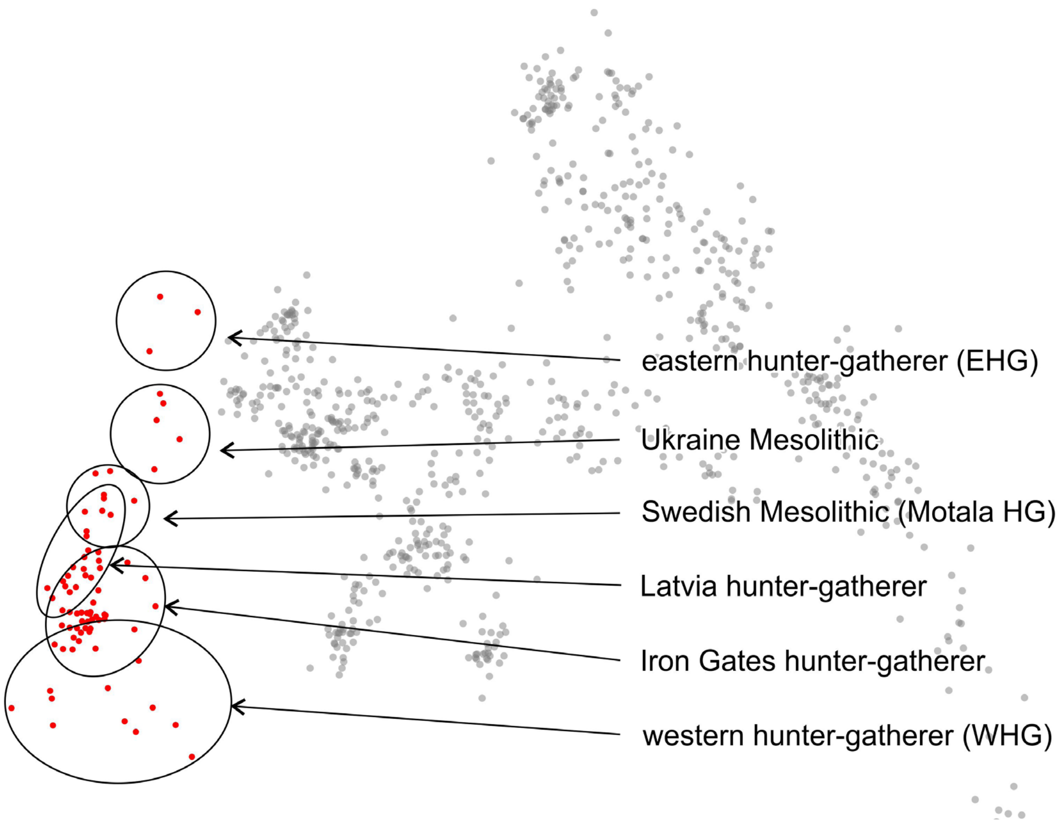


Figure 5. PCA plot redrawn from Mathieson et al. 2017: Extended Data Figure 1.

ordered set of gestures and actions that lead to the transformation of raw material to a finished product, is regarded as a socially transmitted system the use of which is indicative of group affiliation (e.g., Karlin & Julien 1994; Lemonnier 1990).

Gradual change in the *chaînes opératoires,* on the other hand, is best explained by cultural evolution and especially by the ways it structures the transmission of socially acquired information (Mesoudi & O'Brien 2008; Riede 2006), while the speed of change is potentially enhanced by constraints set by the physical environment, such as raw material or prey availability. This means that although history explains a considerable part of the way things are done, in the long run socially transmitted operational sequences are not static but instead subject to evolution (Manninen 2014).

With these premises in mind, technological studies in the *Pioneers of North-Western Europe* -project aim at detecting patterns that indicate migration of people and/or transmission of information and skills from the two major late-glacial cultural areas located at the gates of the (then) largely ice-covered Scandinavian peninsula, namely the Terminal Paleolithic/Early Mesolithic cultures of the northern parts of the East European plain, i.e., the "post-Swiderian" groups, and the North-European late-glacial groups known best from the areas of present-day Denmark and northern Germany, that is, the Ahrensburgian and related groups.

The stone tool technology of the early inhabitants of Norway was to a large degree based on lithic blade production. Experimental studies have shown that blade production by differing operational chains leave tell-tale signs in the resulting end-products and waste, which in some cases are very distinct (e.g., Inizan et al. 1999; Pelegrin 2012). These traces, or *stigmata*, can be used to detect and separate differing technological traditions. Recently, the recognition of the use of a pressure technique to produce regular blades from conical to semi-conical cores in the early post-glacial assemblages from Finland and Norway (Inizan 2012; Jussila et al. 2012; Kankaanpää & Rankama 2012; Knutsson & Knutsson 2012; Manninen & Hertell 2011; Rankama & Kankaanpää 2011; Sørensen et al. 2013; Damlien 2016), has brought new evidence to support a north-eastern route for the migration of people and knowledge to northernmost Norway in the early Holocene.

At the moment, the eastern or "post-Swiderian" technology can be distinguished by the use of pressure blade technology and related core preparation methods (see Sørensen et al. 2013; Damlien 2016 for detailed technological descriptions). A probably related technology (see Knutsson et al. 2016; Manninen et al. 2018), that is, slotted point manufacture using the so called Z-method (Zamostje) is also distinguished in the east, while blade production by direct percussion and opposite platform cores as well as bone tool production using the so-called D-method (Danish) is characteristic for the "western" epi-Ahrensburgian and Maglemosian assemblages (Figure 6; David 2009; Sørensen et al. 2013; Bergsvik & David 2015).

The presence of this technology in southern Norway and south-eastern Sweden by ca. 8000 BC is suggested to indicate spreading of the technology from north to south in Norway and the speed at which this happened according to radiocarbon dating, to indicate probable population migration (Sørensen et al. 2013; Damlien 2016).

Figure 6. The border zone (dotted line) between the North European (Maglemosian) bone technology (D-method) and the North-East European bone technology (Z-method) at ca. 7500-6000 BC (after Bergsvik & David 2015) and pre 7000 BC finds of slotted bone points in northern Europe (black dots). Dates indicate median values calculated using OxCal 4.2 (IntCal 13) on the earliest cluster of dates per site that the r_combine function of the program combines without error warning (approximately 200 year bins). When available, bone dates have been preferred over charcoal dates). Slotted bone point data from Edgren 1997; Carpelan 2008; Hartz et al. 2010; Skakun et al. 2011; Persson 2014; Kjällqvist et al. 2016; Knutsson et al. 2016; Jussila, T., Kriiska, A. & Rostedt, T. pers. comm. 2016.

However, the relatively early occurrence of the technology in south-eastern Sweden and southern Norway could also be a consequence of a southern route directly from the eastern Baltic across or around the Baltic Sea basin (Figure 7) – possibly using dog sleds on sea ice. However, it is unclear how the speed of technology spreading through horizontal transmission of knowledge and know-how in a low population density situation would differ from that of population migration. It should be noted, that technological concepts that can be related to an early post-glacial eastern influence in Scandinavia, at present are confined to the eastern Early Mesolithic blade core treatment process and slotted bone points with straight blade insets, while blade arrowheads of the "post-Swiderian" types are not known from Norway and Sweden (Sørensen et al. 2013) but are present at many pioneer stage sites in the eastern Baltic and Finland (e.g., Zhilin 2006; Manninen & Hertell 2011).

Ancient DNA

Southern Sweden seems to have been the receiver of substantial immigration associated with the introduction of agriculture ca. 4000 BC. In Sweden there are known Early Neolithic agricultural sites close to the coast up to the area around Stockholm (Sørensen 2015). In Norway

Figure 7. Early post-glacial sites and suggested colonization routes to Norway from Ahrensburgian (red) and post-Swiderian (black) cultural spheres (modified from Sørensen et al. 2013). Red dots indicate a selection of radiocarbon dated early sites with reported Ahrensburgian or epi-Ahrensburgian technology. Black dots indicate a selection of early sites with reported post-Swiderain technology. Dates indicate median values calculated using OxCal 4.2 (IntCal 13) on the earliest cluster of dates per site that the r_combine function of the program combines without error warning (approximately 200 year bins). When available, bone dates have been preferred over charcoal dates). Data from Meling 2008, Brinch Petersen 2009, Oshibkina 2008, Hartz et al. 2010, Hertell & Tallavaara 2011, Jussila et al. 2012, Gjerde & Hole 2013, Pesonen et al. 2014; Damlien 2016.

those first agriculturalists had a limited spread restricted to the area around the south-eastern part of Oslofjord next to Sweden. For the rest of Norway the hunter-gatherer way of living continued for most of the Neolithic. It is first in the Late Neolithic, around 2000 BC, that agriculture spread on a larger scale in Norway, most probably by new immigrants (Lazaridis et al. 2014; Haak et al. 2015). The same is the case for northern Sweden and Finland. Parts of the Mesolithic genome is still present in today's Norwegian population. In fact, together with Finland and Sweden, Norway has a greater proportion of Mesolithic traits in the human genome than any other country in Europe. Since remains of very few Mesolithic individuals are found in Norway, and nearly none from Finland and northern Sweden, it is tempting to use individuals from later periods to reconstruct the Early Mesolithic genetics. This is, however, complicated, as gene flow between European Mesolithic and Neolithic groups happened already before the Neolithic groups arrived to Fennoscandia. It has for instance been proposed that the Early Neolithic Funnel Beaker Culture people already had a West European Mesolithic element when arriving into Scandinavia (Chyleński et al. 2017, and references within).

The first condition for the use of genetics in tracing the origin of the Mesolithic population in Norway is therefore that Mesolithic individuals from the area need to be included in the study. A second condition is that there were considerable genetic differences between the potential areas of origin for the pioneer colonizers of north-western Europe at ca. 10,000 BC. Small and isolated refugia during the LGM are a potential source for such genetic divergence through the genetic bottleneck effect. However, recently it has been discussed whether settlement in fact was restricted into geographically isolated refugia during the LGM, or not (Banks et al. 2008; 2011; Tallavaara et al. 2015).

William E. Banks and co-workers applied "eco-cultural niche modeling" in two papers (Banks et al. 2008; 2011). In the study they begin with archaeological site locations and map areas that have similar environmental conditions as the surroundings of the known sites. From this they produced a model of LGM settlement in Europe. The result suggests that settlement was very restricted, with a population of only a few thousands during the LGM (Banks et al. 2011: 370). If such small populations are isolated for a longer time, they will get genetic characteristics, and it will be possible to distinguish their descendants when population expansion occurs alongside better climatic conditions. Miikka Tallavaara and co-workers (2015), on the other hand, used niche modeling as well as ethnographic and archaeological data to study LGM population density with climate envelope modeling tools. Their results indicate continuous human population through the LGM in large areas in Europe, thus undermining the idea of isolated refugia with small populations. Their results suggest a continuous population with a minimum size of 130,000 individuals at 21,000 BC. The bottleneck effect would, if this is correct, not give rise to any drastic genetic differences in a population of this size. The genetic differences would instead be gradual over the distribution area and depend on the degree of mobility.

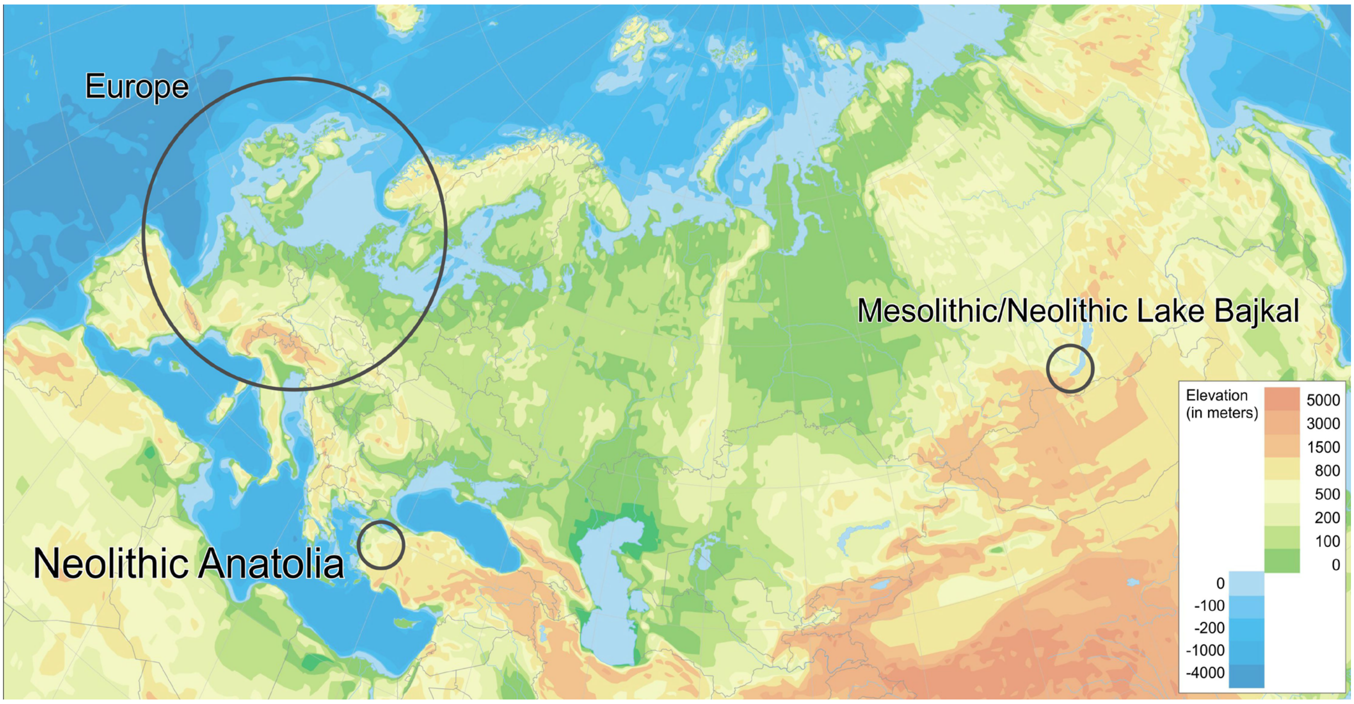
From the aDNA results achieved so far, it seems likely that there were at least some isolated enclaves during the LGM. Most obvious is the difference between the eastern Mediterranean and Western Europe. The groups that came into Europe at the start of the Neolithic had their origins somewhere in the Middle East. The genetic difference between the Mesolithic and the incoming Early Neolithic population in central Europe around 5500 BC may therefore derive from populations descending from groups isolated in two separate LGM refugia. The more precise place of origin for the Early Neolithic population has been subject to some speculation. It is logical to think that they came from Anatolia to Europe, but the fact that the Early Neolithic people happened to have genetic similarities with present day Sardinians has caused some confusion (Sikora et al. 2014). However, recently results from Neolithic Turkey (Mathieson et al. 2015) as well as Neolithic and Mesolithic Greece (Hofmanová et al. 2016) confirm that the Neolithic farmers originated in eastern Mediterranean. In addition, the study by Zuzana Hofmanová and co-workers (2016), which includes two Mesolithic samples from Greece, shows that these two individuals belong to the K1c mitochondrial haplogroup, a group typical for the Early Neolithic in Europe and Anatolia while unknown among Mesolithic individuals from other parts of Europe. The most likely explanation for this is that the ancestors of the two Mesolithic individuals from Greece on one hand, and the Mesolithic individuals from the rest of Europe, on the other, were located in different refugia during the LGM.

The parts of the world from which human aDNA results are available, are still quite restricted, but an area of interest in this connection is Lake Baikal where several individuals have been sampled (Vahdati Nasab 2011). Stone Age burials in the area have yielded samples with considerably different mtDNA haplogroup composition when compared to both Mesolithic Europeans and Early Neolithic Anatolians (Figure 8). Lake Baikal is far from Europe, ca. 5000 km east of Moscow, so it may not be a surprise that the mtDNA composition there is quite different from both Mesolithic and Early Neolithic Europe. However, Lake Baikal is relatively close to the presumed eastern LGM refugium, and if the model presented by Tallavaara and co-workers (2015) is correct, there was nothing to hinder east-west contact over southern Siberia. Despite this, there is only minor overlap with Mesolithic Europe and Anatolian Neolithic.

The ways mtDNA groups have been ascribed to different refugia in Europe are not uniform between researchers. As most of the Mesolithic individuals studied belong to U5, U4 or U2, the discussion on the origin of the Mesolithic population in Europe can be restricted to these groups. Most researchers seem to agree that U5a and U5b originated in separate refugia. U5b in a western refugium, while U5a together with U4 and U2, both are considered eastern (Pala et al. 2012). Mapping of the distribution of these mtDNA types in the studied Mesolithic individuals shows that there is a tendency for U5b to have a more limited distribution centering in south-western Europe. It can be noted that so far a Mesolithic individual belonging to the U5b haplogroup has not been found in Scandinavia or north of Latvia in the north-east (Figure 9). If this reflects a real absence of U5b in northern Europe, it may suggest that all of the Mesolithic population in Scandinavia derived from eastern female ancestral lines.

While the mtDNA is inherited strictly from mother to child, the effect of mixing on the genomic DNA is that a child will locate genetically between the two parents. The 82 Mesolithic European individuals with genomic information investigated by Mathieson et al. (2017) fall in a continuum with one endpoint in individuals from SW Europe and the other in individuals from Russia. (Figure 5). The Swedish individuals appear to be a group of their own in this respect, placed about midways between the two endpoints. This could either be interpreted as an indication of at least three different LGM refugia and that the Swedish Mesolithic individuals are representatives of one of these and thus forming a separate group, or alternatively, the results could indicate that there were two populations representing separate LGM refugia, one south of Scandinavia and one to the east, which expanded when the ice withdrew, and met and got mixed in Scandinavia. The latter explanation fits with the archaeological evidence suggesting that Scandinavia first got Early Mesolithic pioneers from the south and slightly later a second wave of human dispersal from the northeast.

All skeletal remains found on the Scandinavian Peninsula so far are dated after 8000 BC, i.e., after the change in stone technology assumed to indicate immigration from east. Therefore is it not possible to directly investigate if the change



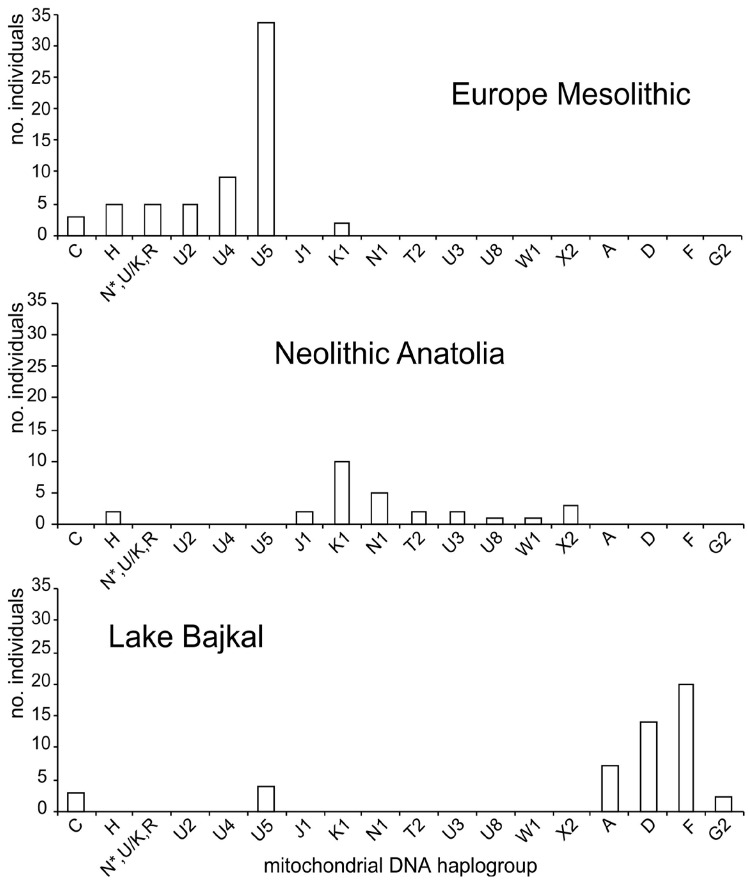


Figure 8. The mtDNA haplogroup from three areas, divided in major groups. According to the research situation early in 2016; Europeans are 73 individuals, Neolithic Anatolia are 28 individuals from Mathieson et al. 2015, Extended data table 1 and Hofmanová et al. 2016, Tab 1, Lake Baikal are 50 individuals from Vahdati Nasab 2011, Tab 4 (the two undefined "non-asians" in Vahdati Nasab's total of 52 individuals not used here).

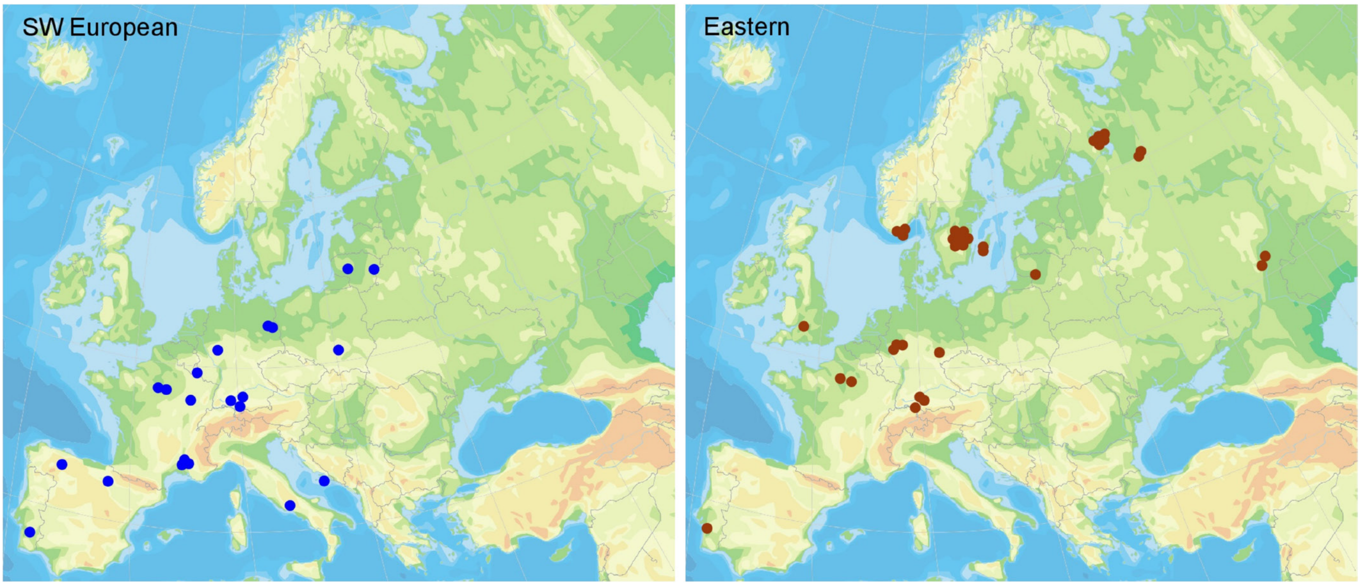


Figure 9. The mtDNA haplogroups ascribed to a south-western refugium (U5b) and an eastern refugium (U2, U4 and U5a). Sources: Chandler et al. (2005), Haak 2006, Bramanti et al. 2009, Delsate et al. 2009, Der Sarkissian 2011, Hervella et al. 2012, Bollongino et al. 2013, Brandt et al. 2013, Skoglund 2013, Lazaridis et al. 2014, Olalde et al. 2014, Skoglund et al. 2014, Haak et al. 2015, Mathieson et al. 2015, Fu et al. 2016, Szécsény-Nagy 2015, Posth et al. 2016.

in stone technology is connected with a genetical change. However, if Mesolithic Scandinavians were mostly a mix of people deriving from two refugia, an analysis of their DNA sequences will make it possible to estimate the probabilities for this mixing happening before or after these groups arrived into Norway.

Modeling the past

The re-colonization of north-western Europe was part of a larger process in Europe that started with the end of the Last Glacial Maximum, ca. 18,000 BC. For humans, the development from LGM to Holocene in Europe meant changes in environmental conditions, social organization, technological knowledge, and equipment, with accelerating speed. However, there is no way to grasp the effects of these changes for the population growth and dispersal in simple mathematical formulas. The logistic population growth model, for instance, presupposes one population in one delimited geographical area with a stable environment. In order to get a realistic view of the development, the model should be dynamic both in time and space. In our project we will use computer simulations in which all the individuals in the model will be entities represented with individual sex, age, and other characteristics. The procedure therefore differs from models in which the entire population is represented by a single value, the sexes represented by a fraction of the population, etc. In our simulation the modelled individuals will also acquire a place on the map and can move around in the geography (it will, in that respect, be an "agent based model", cf. Romanowska 2015). The model will be dynamic as it is run in one year time steps while the individuals grow older every year until they eventually die. Changes in the environment, such as the retreat of the ice sheet, changes between land and sea, and so forth, will be modelled on a coarser time scale, but updated continuously in accordance with what is known of the environmental changes. A similar approach has recently been applied by Tarja Sundell and co-workers to periods post-dating the pioneer colonization phase in Finland Sundell et al. 2010; 2014).

This model will make it possible to simulate different scenarios for the pioneer settlement of north-western Europe and consequently allows comparison of the modeled scenarios with what is known from archaeological and genetic research. For instance, it will be possible to compare the outcome of simulations with and without isolated refugia in southern Europe during LGM. Different scenarios in this respect can result in quite different genetic and cultural patterns 10,000 years later.

As discussed earlier in this paper, ancient DNA indicates that there were considerable changes in European population since the end of the last glacial period, especially with the immigrations in the Neolithic (Haak et al. 2015, Mathieson et al. 2015) and that therefore it is not possible to reconstruct the course of events using only the genes of people living in Europe today. Ancient DNA from a few Mesolithic and Neolithic individuals, however, improves the situation considerably. If we accept that mtDNA haplogroups U5a and U5b were established before the end of LGM, we can simulate the fate of these groups through time. It might, for instance, be possible to decide whether individuals with U5a or U5b mtDNA haplogroups dated to Neolithic, descend from the local Mesolithic people or represent new Late Neolithic immigrants as proposed by Guido Brandt (2015; Brandt et al. 2015). Moreover, if local Mesolithic origin is the most likely scenario, these individuals can be used as representatives of the Mesolithic population despite their late date and yield a valuable addition to the few Mesolithic individuals available, while providing information on the line of events during the Mesolithic.

Simulations of geographical trends with an ecological model are similar to phylogeography carried out for many species in regard to their refugial history and dispersal after the LGM. These studies infer population dynamics mainly from genetic signatures that are still detectable today. For warmth-demanding species, with refugia in southern Europe, a decreasing gradient of diversity is expected from south towards the north, with maximum levels of variation in putative glacial refugia. This is the case with wild boar (Vilaça et al. 2014), as well as red and roe deer (Sommer et al. 2008; Sommer et al. 2009).

Concluding remarks

The history of research into the early colonization of northern Europe shows a tight connection between Late Paleolithic archaeology and ecology, as it was deglaciation that provided new land for the expanding population at the end of the last glacial cycle. Connections also exist between linguistics and archaeology especially in early treatments of the subject, as archaeological cultures have been seen as representing precursors for later historical language groups. Purely archaeological studies of the subject have relied mostly on tool types. Since the late 20th century, references to genetics and technological trajectories have increased in number, initially quite slowly, but recently in rapidly increasing numbers. The genetic data available today seems to be in favour of separate glacial refugia for humans, as well as other species, during the LGM, while archaeological data strongly points towards early post-glacial human dispersal to Norway from two directions. The challenge for our project is to combine the available knowledge with a focus on Early Mesolithic Norway and contribute with new data on aDNA and movement of technological knowledge and know-how in early post-glacial Europe.

This article was written in 2017. Since then new contributions on the genetics of the Mesolithic populations on the Scandinavian Peninsula have been published (Kashuba et. al. 2019, Günther et al. 2018).

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Lipid residues in early hunter-gatherer ceramics from Finland

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Abstract

The adoption of pottery technology by hunter-gatherers in the Baltic region has mainly been placed within the concept of resource intensification, as a cultural choice that assisted an increased economic focus on aquatic resources. In Finland, a non-specialized pottery use has earlier been suggested on the basis of lipid residue analysis data for Early Neolithic[1] ceramics from a number of sites on the south-west coast that involve processing of both aquatic and terrestrial animal products. Our study is an attempt to further explore the relationship between the early pottery use, diet and environment in this particular region. For this purpose, we expanded the range of early pottery traditions and localities to be analyzed, and applied gas chromatographic and mass spectrometric (GC-MS) analysis on the absorbed lipid residues. The study material comprises ceramics of the Säräisniemi 1 (Sär 1), Sperrings 1 (Ka I:1) and Sperrings 2 (Ka I:2) pottery traditions, as well as of the Jäkärlä Ware group, from coastal and inland sites spanning a period from *ca*. 5100 to 4000 cal BC. Our results strengthen the above observation for Early Neolithic Finland and further suggest that both aquatic and terrestrial animal resources were processed in vessels belonging to most of the analyzed groups, irrespective of coastal/inland site division and pottery ware culture. This additionally indicates a variability of motives behind the introduction of pottery within the Baltic Sea region, considering pottery use evidence in the neighbouring Estonia, where the earliest local and contemporaneous Narva pottery culture had a more specialized use focused on the processing of aquatic resources.

Keywords: Early Neolithic, ceramics, hunter-gatherers, lipid residue analysis, biomarkers, GC-MS, Finland

Introduction

The early stages of pottery utilization by hunter-fisher-gatherer populations in various geographical regions and from different periods of time have been connected with subsistence strategies that involved new and more efficient ways to exploit the sustainable and nutrient-rich marine and freshwater resources (Jordan & Zvelebil 2009; Craig et al. 2013; Gibbs & Jordan 2013; Farrell et al. 2014; Taché & Craig 2015). In the West Baltic region, organic residue analysis of ceramic vessels indicated that pre-agriculture pottery-using populations living by the coast relied heavily on marine resources for their subsistence, and high aquatic food consumption was observed inland as well (Andersen 2008; Craig et al. 2011). Another more recent study of lipid residues conducted on the earliest ceramics from Estonia of the Narva Ware culture showed similar results that suggest a specialized use for the processing of aquatic products irrespective of site division, coastal or inland, despite the availability of land animal resources in the landscape (Oras et al. 2017). The authors argue that the findings invigorate the above hypothesis for the uptake of ceramics by foragers, and propose that pottery possibly supported the intensification of aquatic resource exploitation during seasons of higher productivity, which in turn led to increased sedentism and population densities (Oras et al. 2017). Moreover, an earlier study on Narva-type vessels from the coastal Sventoji site, Lithuania, although dating later, corroborates the above with evidence that also suggests a pottery use orientated to the processing of aquatic foodstuff (Heron et al. 2015).

In Finland, the application of organic residue analysis on archaeological ceramic vessels is still a novel line of research in the field of ceramic studies, although its potentials were fully realized quite early. There are so far only a few published studies with lipid identifications on organic residues from ceramics. The earliest concerned fatty acid analysis of charred surface deposits from Bronze Age sherds recovered from the Otterböte site, Åland, with the aim to investigate whether marine and specifically seal blubber lipids could be identified. One of the four analyzed samples showed positive results (Isaksson 1997). Typical and Late Comb Ware charred surface crusts from the Vantaa Maarinkunnas site were also analyzed for their lipid composition, with results suggesting mainly aquatic animal origins (Hopia et al. 2003; Leskinen 2003; Pesonen & Leskinen 2009). Another more comprehensive study was performed a few years ago, and included both molecular and stable carbon isotope analysis of individual fatty acids (Cramp et al. 2014). The analyzed material here covers a timespan from the fourth to the first millennium BC, comprising Typical Comb Ware, Corded Ware, Kiukainen Ware, Late Bronze Age and Early Iron Age Morby Ware ceramics. For the Typical Comb Ware pots, the results pointed to a predominant or exclusive use for the processing of marine resources. Dairy fats were mainly suggested for the Corded Ware, Bronze Age and Morby Ware pots, while Kiukainen Ware demonstrated mixing of ruminant and non-ruminant/marine fats (Cramp et al. 2014). The most recent study undertaken by Pääkkönen et al. (2016) was the first attempt on Early Neolithic material that allowed for interpretations about the function of ceramics at the initial stages of their introduction in this area. The analyzed residues derive from three coastal sites of the Early Comb Ware and Jäkärlä Ware cultures situated in south-west Finland and the results showed that both aquatic and terrestrial animals, basically ruminants, had been processed in the vessels. This

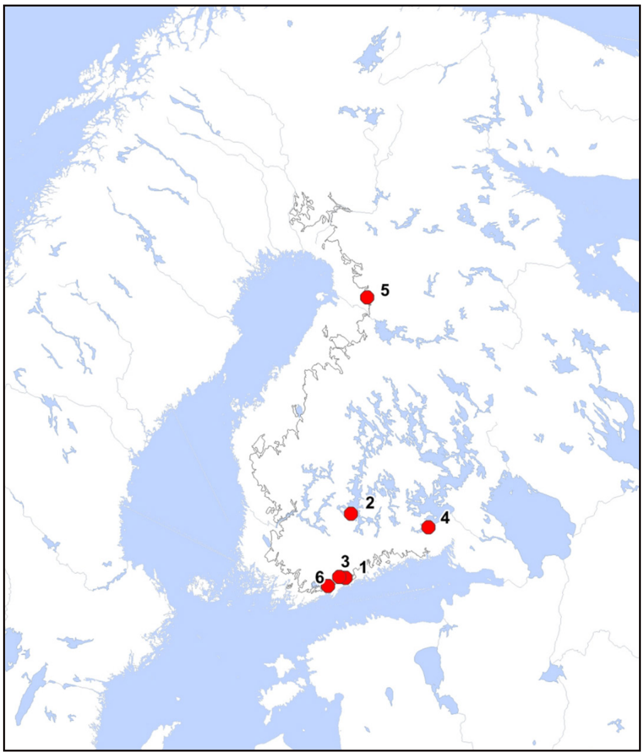

Figure 1. The sampled sites: 1– Vantaa Etelä- Vantaa 3/Mätäoja III (Palmu); 2– Padasjoki Leirintäalue; 3– Espoo Kläppkärr; 4– Lappeenranta (Etu-ja Taka) Muntero; 5– Oulu (formerly Ylikiiminki) Vepsänkangas; 6– Raasepori Telegrafberget. The grey line corresponds to the Littorina Sea phase of the Finnish coast ca. 6100 cal. BC (adapted from Tikkanen & Oksanen 2002).

gives another dimension for the early pottery use in the circum-Baltic region and challenges the hypothesized link of hunter-gatherer ceramics to subsistence/economic strategies connected with the exploitation of aquatic resources. Our study comes to contribute to this evidence with the aim to further explore the early pottery use and dietary habits in Finland through analysis of Early Neolithic ceramic sequences from different chronological phases and environments, coastal and inland, all located close to water systems (Figure 1; see also Appendix). We provide molecular (GC-MS) data of the absorbed residues.

Materials and Methods

A total of 22 potsherds from Säräisniemi (Sär 1), Sperrings 1 (Ka I:1), Sperrings 2 (Ka I:2) and Jäkärlä Ware ceramic vessels (Table 1) were carefully selected for molecular analysis by gas chromatography – mass spectrometry (GC-MS) by excluding sherds with adhesives from previous conservation treatments and paying extra caution to avoid multiple sampling of singular vessels. They all seem to derive from large vessels judging from the flatness of the sherds (Figure 2). Coastal sites were sampled for the Sär 1 and Jäkärlä Ware pottery styles, and both coastal and inland ones for the Ka I:1 and Ka I:2. A sample amount of *ca.* 1.0–2.0 grams of ceramic powder was ground off from the interior surface by using a low-speed pottery grinder. Powder was collected on clean sheets of aluminium foil and transferred quantitatively in tubes after preliminary grinding and removal of the first ca. 1.0 mm of the surface to reduce possible interference of extraneous lipid sources, such as fingerprints or soil. All glassware used had previously been washed with dichloromethane (DCM).

Lipid extraction and derivatization

Before extraction, the pulverized samples were washed with a DCM/CH_3OH solution (2:1, v:v; 3*3.0 ml) to remove any remnants of exogenous lipids, following the protocol described by Lucquin et al. (2016). Lipid extraction and derivatization was accomplished by using a one-step acid extraction and methylation protocol as it was described in Papakosta et al. (2015). Briefly, an amount of 1.0 ml, or 2.0 ml, of CH_3OH acidified with concentrated H_2SO_4 (200 µl) as catalyst was used to release lipids, depending on the sample amount. The samples were heated for 4 h at 70°C. After heating, *n*-hexane was added (1.0 ml), and separated from CH_3OH after a three-time repeated centrifugation (3000 rpm, 5 min).

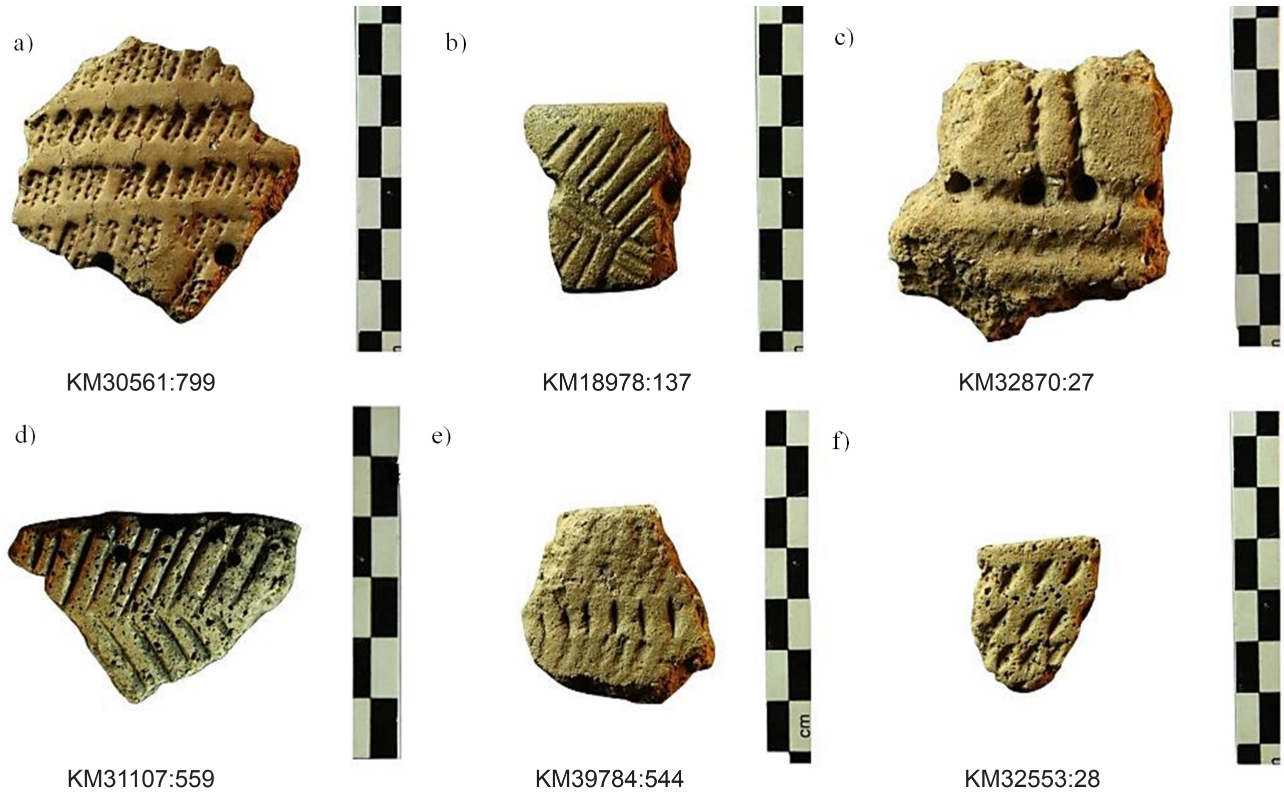

Figure 2. Examples of analyzed potsherds: a– Sär 1; b, c– KaI:1; d, e– KaI:2; f– Jäkärlä Ware (photos by P. Pesonen, modified by V. Papakosta).

The combined extracts were evaporated under a gentle stream of N_2 gas and treated with 100 µl of bis(trimethylsilyl)trifluoroacetamide (BSTFA) containing chlorotrimethylsilane (TMCS, 10%) to mask any underivatized hydroxyl groups. Then, they were heated at 70°C for 25 min, evaporated, and rediluted in *n*-hexane for GC-MS analysis.

Molecular analysis by gas chromatography - mass spectrometry (GC-MS)

Separation and identification of the extracted lipids was performed on a HP 6890 Gas Chromatograph fitted with a SGE BPX5 fused-silica capillary column (15 m x 220 µm x 0.25 µm), coupled to a HP 5973 Mass Selective quadrupole detector. Samples were injected through a Merlin Microseal™ High Pressure Septum in pulsed splitless mode (pulse pressure 17.6 Psi, 325°C). The column oven was set to start with an initial isothermal at 50°C for 2 min, and then temperature increased to reach 360°C with a rate of 10°C per minute. A final isothermal hold was set for 15 min. Helium was selected as the carrier gas with a controlled constant flow of 2.0 ml/min. Ionization and fragmentation of the compounds were accomplished by electron impact (70 eV) with the aid of an ion source maintained at 230°C. The mass filter was set to scan between *m/z* 50 and 700 with a rate of 2.29 scans per second. Quantification was performed using the calibration line of the saturated C_{17} fatty acid methyl ester measured in different concentrations after treatment with the same protocol. Where present, compounds considered as contamination, mainly phthalates, were excluded from integration of the total peak areas of the total ion chromatograms.

Table 1. Sampled sites and weighed amount of ceramic powder from each of the selected samples.

Site/Site location	Sample Inv. no.	Sample Lab no.	Sample amount (in g)
Oulu (formerly Ylikiiminki) Vepsänkangas	KM30561:725A	Ou725A	1.9
/ Sär 1; Coastal	KM30561:725B	Ou725B	0.7
	KM30561:793	Ou793	1.8
	KM30561:799	Ou799	1.9
Vantaa Etelä-Vantaa 3/Mätäoja III (Palmu)	KM18978:139	V78:139	2.0
/ KaI:1; Coastal, close to river estuary	KM18978:146	V78:146	1.6
	KM18978:106	V78:106	1.7
	KM18978:137	V78:137	1.8
Padasjoki Leirintäalue	KM32870:27	P70:27	1.9
/ KaI:1; Inland, lakeside			
Espoo Kläppkärr	KM31107:559	E07:559	1.8
/ KaI:2; Coastal	KM31107:600	E07:600	1.9
	KM31107:468	E07:468	1.8
	KM31107:456	E07:456	1.8
Lappeenranta (Etu-ja Taka) Muntero	KM39784:11764	LPR11764	1.6
/ KaI:2; Inland, lakeside	KM39784:11935	LPR11935	1.9
	KM39784:544	LPR544	2.1
	KM39784:1629	LPR1629	1.9
	KM39784:322	LPR322	2.0
	KM39784:117	LPR117	1.9
Raasepori Telegrafberget	KM32553:66	R66	1.6
/ Jäkärlä Ware; Coastal	KM32553:28	R28	1.4
	KM32553:35	R35	1.9

Results and Discussion

The majority of the analyzed samples (55%) exhibit evidence of vessel use most probably associated with cooking, as the detected ω-(o-alkylphenyl)alkanoic acids (APAAs) are formed during heating of unsaturated fatty acids at 260–270 °C (Hansel et al. 2004; Craig et al. 2007; Evershed 2008; Evershed et al. 2008; Heron et al. 2010). Besides APAAs, mid- to long-chain ketones were also detected in two of the samples (E07:559 and LPR11935) that might additionally indicate overheating of food lipids (≥300 °C) (Evershed et al. 1995; Baeten et al. 2013). This observation seems to contradict a previous belief that this function may not have been central for these vessels (cf. Matiskainen 2008: 187).

The significant lipid preservation enabled identification of compounds diagnostic of their origin in most cases. Identification of aquatic resources (marine and/or freshwater) was supported by the presence of their corresponding biomarkers, although not in full set (at least one isoprenoid fatty acid and the C_{18} to C_{22} APAAs, or the C_{20} and C_{22} APAAs), the co-occurrence of broad series of diacids (DAs), *i.e.*, oxidation products of unsaturated fatty acids, the occasional persistence of the $C_{20:1}$, $C_{22:1}$ and $C_{24:1}$ fatty acids, and fatty acid distributions dominated by the saturated C_{16} homologue that give $C_{18:0}/C_{16:0}<0.48$ ratios (Tables 2-3; Figure 3) (Ackman & Hooper 1970; Regert et al. 1998; Hansel et al. 2004; Olsson & Isaksson 2008; Boudin et al. 2009; Cramp & Evershed 2014). In samples where these sets of compounds concurred with high $C_{18:0}/C_{16:0}$ ratios (>0.48), possible mixing with terrestrial animal fats is suggested (Romanus et al. 2007).

In the coastal Sperrings 1 (Ka I:1) Vantaa Etelä-Mätäoja III (Palmu) site, all samples demonstrate high $C_{18:0}/C_{16:0}$ ratios (>0.48) typical of terrestrial animal fats as the dominant components in the residues. Intriguingly, no aquatic biomarkers have been detected, such as isoprenoids and APAAs, that could point to a contribution of aquatic products as it would be expected considering the site location and the predominance of seal bones in the analyzed osteological material (Table 2–3; Appendix). Some possible vegetal input in the form of a plant-deriving oily substance could also be assumed by the short ranges of DAs (C_8-C_{10}) detected in three of the samples.

In the chronologically contemporaneous inland Ka I:1 Padasjoki Leirintäalue site, both terrestrial and aquatic animal products were processed in the single analyzed pot (P70:27), as it is inferred by the high $C_{18:0}/C_{16:0}$ ratio (>0.48) and the co-occurrence of phytanic acid with the full range of APAAs (C_{16}–C_{22}) in very low abundances and a broad series of short- to medium-chain DAs (C_7-C_{12}) (Table 2–3; Figure 3). It is worth noting that phytanic acid is not an aquatic biomarker in itself as it is also found in ruminant carcass fats and dairy products (Vetter & Schröder 2011; Cramp & Evershed 2014). The analyzed archaeofaunal material from the site is represented accordingly by both land and aquatic animals, with fishbone fragments being the most abundant (Appendix).

Three out of four samples from the contemporaneous coastal Sär 1 Oulu (Ylikiiminki) Vepsänkangas site demonstrate high $C_{18:0}/C_{16:0}$ ratios (>0.48) indicative of terrestrial animal fats (Table 2). However, the lipid profile of one of them (Ou725B) does not seem to represent food residues, but most probably coniferous resin or tar, according to the presence of dehydroabietic acid that was the most abundant compound (Pollard & Heron 1996: 240–5). These substances

Table 2. Summary of the GC-MS results for each of the analyzed samples. SFAs= saturated fatty acids, LCALs= long-chain alkanols, ALs= alkanes, BRFAs= branched fatty acids, MUFAs= monounsaturated fatty acids, DAs= diacids (dicarboxylic acids), LCKs= long-chain ketones, APAAs= ω-(o-alkylphenyl)alkanoic acids, DT= dehydroabietic acid, tr.= traces. Cx:y (x denotes the carbon-chain length, y denotes the degree of unsaturation). A C18:0/C16:0 >0.48 ratio indicates a fatty acid distribution indicative of terrestrial animal fats. T= terrestrial animals, A= aquatic animals, P= plants.

Sample	Lipid concentration (µg g^{-1})	$C_{18:0}$/ $C_{16:0}$ (>0.48)	Compounds detected	Interpretation
Ou725A	150	1.3	SFAs ($C_{10:0}$-$C_{26:0}$), LCALs ($C_{22:0}$, $C_{24:0}$), ALs ($C_{14:0}$-$C_{25:0}$), BRFAs (C_{15}, C_{17}, C_{18}), MUFAs ($C_{16:1}$, $C_{18:1}$), DAs (C_6-C_{12}), phytanic acid, APAAs (C_{16}-C_{22}), cholesterol, 3, 5-cholestadienone, (2-TMS-oxy) $C_{16:0}$, DT tr.	T A
Ou725B	70	1.0	SFAs ($C_{12:0}$-$C_{26:0}$), LCALs ($C_{22:0}$, $C_{26:0}$), ALs ($C_{16:0}$-$C_{24:0}$?), BRFAs (C_{15}, C_{17}), MUFAs ($C_{18:1}$), DAs (C_8, C_9), b-sitosterol, DT	Coniferous resin/ tar
Ou793	30	0.9	SFAs ($C_{9:0}$-$C_{28:0}$), ALs ($C_{15:0}$-$C_{20:0}$), BRFAs (C_{15}, 10-methyl-, 14-methyl-C_{17}), MUFAs ($C_{16:1}$, $C_{18:1}$), DAs (C_8, C_9), DT tr.	T
Ou799	140	0.3	SFAs ($C_{9:0}$-$C_{24:0}$), ALs ($C_{16:0}$-$C_{18:0}$, $C_{22:0}$-$C_{24:0}$), BRFAs (C_{15}, C_{17}, C_{18}), MUFAs ($C_{16:1}$, $C_{18:1}$), DAs (C_7-C_{12}), phytanic acid, APAAs (C_{16}-C_{22})	A
V78:139	40	0.9	SFAs ($C_{12:0}$-$C_{26:0}$), ALs ($C_{16:0}$-$C_{26:0}$), LCALs ($C_{22:0}$, $C_{26:0}$), BRFAs (C_{15},C_{16}), MUFAs ($C_{18:1}$), DAs (C_8-C_{10})	T P
V78:146	40	1.0	SFAs ($C_{12:0}$-$C_{26:0}$), ALs ($C_{16:0}$-$C_{27:0}$), BRFAs (C_{15}-C_{17}), MUFAs ($C_{18:1}$ tr.), DT tr.	T P
V78:106	80	0.9	SFAs ($C_{9:0}$-$C_{28:0}$), ALs ($C_{14:0}$-$C_{25:0}$), LCALs ($C_{22:0}$, $C_{26:0}$), BRFAs (C_{15}-C_{18}), MUFAs ($C_{16:1}$, $C_{18:1}$), DAs (C_8-C_{10}), DT tr.	T P
V78:137	50	0.9	SFAs ($C_{10:0}$-$C_{26:0}$), ALs ($C_{15:0}$-$C_{26:0}$), BRFAs (C_{15}-C_{17}), MUFAs ($C_{16:1}$,$C_{18:1}$), DAs (C_8, C_9), DT tr.	T P
P70:27	40	0.8	SFAs ($C_{12:0}$-$C_{24:0}$), ALs ($C_{16:0}$-$C_{24:0}$), BRFAs (C_{15}, C_{17}, C_{18}), MUFAs ($C_{18:1}$), DAs (C_7-C_{12}), phytanic acid, APAAs (C_{16}-C_{22}), DT tr.	T A
E07:559	1010	0.36	SFAs ($C_{9:0}$-$C_{24:0}$), ALs ($C_{13:0}$-$C_{17:0}$), BRFAs (C_{13}-C_{19}), MUFAs ($C_{18:1}$), DAs (C_7-C_{12}, C_{14}, C_{16}, C_{18}), phytanic acid, APAAs (C_{16}-C_{22}), LCK (C_{31}, C_{32}), 5-oxo-($C_{16, 18, 20, 22}$), 3, 5-cholestadienone	A
E07:600	300	0.2	SFAs ($C_{9:0}$-$C_{28:0}$), ALs ($C_{15:0}$-$C_{20:0}$), BRFAs (C_{15}-C_{18}), MUFAs ($C_{16:1}$, $C_{18:1}$, $C_{20:1}$, $C_{22:1}$, $C_{24:1}$), DAs (C_7-C_{14}), phytanic acid, APAAs (C_{18}-C_{22})	A
E07:468	110	0.22	SFAs ($C_{10:0}$-$C_{24:}$0), ALs ($C_{14:0}$-$C_{23:0}$), BRFAs (C_{15}-C_{18}), MUFAs ($C_{16:1}$ tr., $C_{18:1}$ tr.), DAs (C_9-C_{14}), APAAs (C_{16}?, C_{18})	A
E07:456	20	1.0	SFAs ($C_{10:0}$-$C_{28:0}$), ALs ($C_{15:0}$-$C_{24:0}$), LCALs ($C_{22:0}$-$C_{26:0}$), BRFAs (C_{15}, C_{17}, C_{18}), MUFAs ($C_{18:1}$), DAs (C_9)	T
LPR11764	180	0.23	SFAs ($C_{10:0}$-$C_{24:0}$), ALs ($C_{15:0}$-$C_{17:0}$), BRFAs (C_{15}-C_{18}), MUFAs ($C_{16:1}$?, $C_{18:1,}$ $C_{22:1}$), DAs (C_7-C_{12}), phytanic acid, APAAs (C_{16}-C_{22})	A
LPR11935	1150	1.8	SFAs ($C_{9:0}$-$C_{26:0}$), ALs ($C_{15:0}$-$C_{18:0}$), LCALs ($C_{22:0}$-$C_{26:0}$), BRFAs (C_{15}-C_{18}), MUFAs ($C_{18:1}$), DAs (C_8-C_{18}), LCK (C_{31}-C_{33}), phytanic acid, APAAs (C_{16}-C_{18}), (2-TMS-oxy) $C_{18:0}$	T P
LPR544	200	5.5	SFAs ($C_{12:0}$-$C_{28:0}$), ALs ($C_{15:0}$-$C_{20:0}$), LCALs ($C_{22:0}$-$C_{26:0}$), BRFAs (C_{15}-C_{18}), MUFAs ($C_{16:1}$, $C_{18:1}$), DAs (C_9), phytanic acid, APAAs (C_{16}, C_{18}), cholest-7-ene?, (2-TMS-oxy) $C_{18:0}$, DT tr.	T
LPR1629	30	1.0	SFAs ($C_{12:0}$-$C_{26:0}$), ALs ($C_{16:0}$-$C_{19:0}$), BRFAs (C_{15}-C_{19}; 10-methyl-, 14-methyl-C_{17}; 10-methyl-, 14-methyl-C_{18}; 10-methyl-, 14-methyl-C_{19}), MUFAs ($C_{16:1}$ tr., $C_{18:1}$), DAs (C_7-C_{12}), DT tr.	T P
LPR322	10	0.9	SFAs ($C_{12:0}$-$C_{26:0}$), ALs ($C_{16:0}$-$C_{19:0}$), BRFAs (C_{15}-C_{19}; 10-methyl-, 14-methyl-C_{17}), MUFAs ($C_{16:1}$, $C_{18:1}$), DAs (C_9), DT tr.	T
LPR117	200	0.48	SFAs ($C_{9:0}$-$C_{26:0}$), ALs ($C_{16:0}$-$C_{19:0}$), BRFAs (C_{15}-C_{18}), MUFAs ($C_{18:1}$), DAs (C_7-C_{12}), APAAs (C_{16}-C_{22})	A
R66	400	0.5	SFAs ($C_{9:0}$-$C_{24:0}$), ALs ($C_{16:0}$-$C_{20:0}$), BRFAs (C_{15}-C_{18}), MUFAs ($C_{16:1}$, $C_{18:1}$), DAs (C_7-C_{12}), pristanic acid, phytanic acid?, APAAs (C_{18}-C_{22}), (2-TMS-oxy) $C_{18:0}$	A
R28	30	0.8	SFAs ($C_{12:0}$-$C_{26:0}$), ALs ($C_{15:0}$-$C_{25:0}$), BRFAs (C_{17}), MUFAs ($C_{18:1}$ tr.)	T
R35	500	0.7	SFAs ($C_{9:0}$-$C_{26:0}$), ALs ($C_{14:0}$-$C_{25:0}$), BRFAs (C_{13}, C_{15}-C_{18}), MUFAs ($C_{16:1}$, $C_{18:1}$), DAs (C_7-C_{12}), pristanic acid, phytanic acid, APAAs (C_{16}-C_{22})	T A

Table 3. Summary of the GC-MS results by pottery tradition and site location.

Pottery tradition	Site location	No. vessels analyzed	No. vessels yielding aquatic biomarkers[a]	No. vessels with pure[b] aquatic animal signals	No. vessels with indications of pure[c] terrestrial animal signals	No. vessels with indications of mixing (aquatic + terrestrial animal fats)	Aquatic to terrestrial animal ratio (a/t)
Sär 1	Coastal	4	2	1	1	1	1.0
Ka I:1	Coastal	4	-	-	4	-	0.0
	Inland/Lake	1	1	-	-	1	1.0
Ka I:2	Coastal	4	2	3	1	-	3.0
	Inland/Lake	6	2	2	4	-	0.3
Jäkärlä Ware	Coastal	3	2	1	1	1	1.0

[a] At least one isoprenoid fatty acid acid and ω-(o-alkylphenyl)alkanoic acids (C_{18}-C_{22}), or ω-(o-alkylphenyl)alkanoic acids (C_{20}-C_{22}).
[b] No terrestrial animal signals detected. Plant residues may be present.
[c] No aquatic signals detected. Plant residues may be present.

could have been applied to seal the walls of the vessel for waterproofing. No signs of vessel restoration using resin as glue are visible on the potsherd. Indications of the processing of aquatic products occur in two of the samples, either as pure components (Ou799), or in mixture with terrestrial animal fats (Ou725A) (Table 3). In the sample Ou793, the proposed terrestrial animal signals would possibly originate from ruminants based on the presence of positional isomers of the C_{17} branched fatty acid besides the C_{15} homologue. European elk (*Alces alces*) and reindeer (*Rangifer tarandus*) are likely components according to the recorded archaeofaunal material from the site. Generally, a variety of possible components could be attributed to the three of the analyzed vessels that yielded food signals inferring from the wide diversity of species reported in the archaeofaunal dataset from the site, which is composed of terrestrial and aquatic mammals, fish and waterfowl (Appendix).

Aquatic resources seem to dominate in the analyzed pots from the coastal Ka I:2 Espoo Kläppkärr site, while one sample (E07:456) shows indications of terrestrial animal fats. In the pots from the contemporaneous inland Ka I:2 Lappeenranta Muntero site, only two of the six analyzed samples show clear indications of aquatic products as sole components. The presence of phytanic acid and the C_{16} and C_{18} APAAs in two of the samples (LPR11935 and LPR544) having high $C_{18:0}/C_{16:0}$ ratios (>0.48) cannot be used as safe indications of mixing with aquatic products, since these compounds could also originate from ruminant animals (Ackman & Hooper 1970; Craig et al. 2007; Heron et al. 2015) (Figure 3). An aquatic contribution could be possible for the samples LPR11935 and LPR1629 based on the broad sets of DAs detected, however, as these could also derive from plant oils, in the absence of other biomarkers it is not safe to form such an inference. Ruminant origins are proposed for terrestrial animal residues where wide ranges of branched fatty acids and positional isomers were detected. It is also unknown whether our findings agree with the zooarchaeological material from the site since it has not been analyzed.

Generally, fish bones are often reported in high proportions on inland lakeside sites (Ukkonen 1996). Seal bones are also found today in the entire region that was previously covered by the waterbody of the Lake Saimaa, on the shore of which the site was located (Ukkonen 2002). In the coastal Raasepori Telegrafberget site of the Jäkärlä Ware group, both terrestrial animal and aquatic resources seem to be equally represented in the three analyzed pots, either as main components or in mixture (Table 2–3).

The graphic representation (Figure 4) provides a visual overview of our data and shows that aquatic and terrestrial animal resources were both processed in almost all analyzed vessel groups, irrespective of pottery ware culture, time period and environmental setting. More specifically, in the Sär 1 and Jäkärlä Ware ceramics from the coastal sites, and the Ka I:1 ones from the inland, aquatic and terrestrial animal resources have been identified in balanced proportions. In the Ka I:2 ceramics from the coastal site aquatic animal resources are found in higher proportion, and in lower in those from the inland site of the same culture. Our results are generally in agreement with the available zooarchaeological assemblages of the sites, though the relative proportions of aquatic and terrestrial animal resources in the bone material and the analyzed residues differ. A significant divergence was observed in the Ka I:1 ceramics from the coastal site, where despite the clear prevalence of seal bone fragments in the osteological material, no aquatic signals were detected in any of the analyzed pots. Despite the water-centric character of the site and the observed importance of sealing in the local economy, the inhabitants seem not to have used their pots to process seals and generally aquatic resources. This does not necessarily mean that aquatic resources were not of significant dietary importance for the site occupants, since these could have been processed and consumed by means that do not involve pots (Olsson & Isaksson 2008). The importance of fish for their subsistence, however, cannot be estimated since

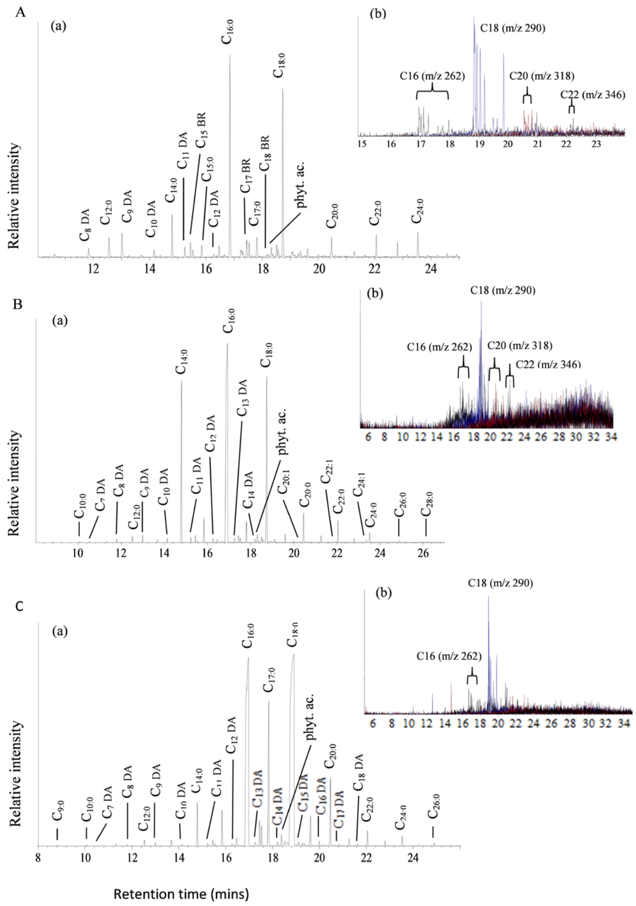

Figure 3. Partial GC-MS chromatograms showing the distribution of fatty acids (m/z 74) and derivatives interpreted as representing, A(a): mixture of aquatic and terrestrial animal products (P70:27), B(a): aquatic products (E07:600), and C(a): terrestrial animal products (LPR11935). A(b), B(b), and C(b) show the range of APAAs detected in each sample.

fish remains do not occur in the archaeofaunal assemblage, perhaps due to the lack of sieving at the early times of the excavation. The degree to which a preferential pottery use towards terrestrial animal resources at this site is valid might be tested through analysis of more samples as we may have missed to sample pots with aquatic residues.

Conclusions

Molecular (GC-MS) analysis of absorbed lipid residues from Early Neolithic hunter-fisher-gatherer pottery sequences from Finland enabled interpretations on pottery use thanks to the

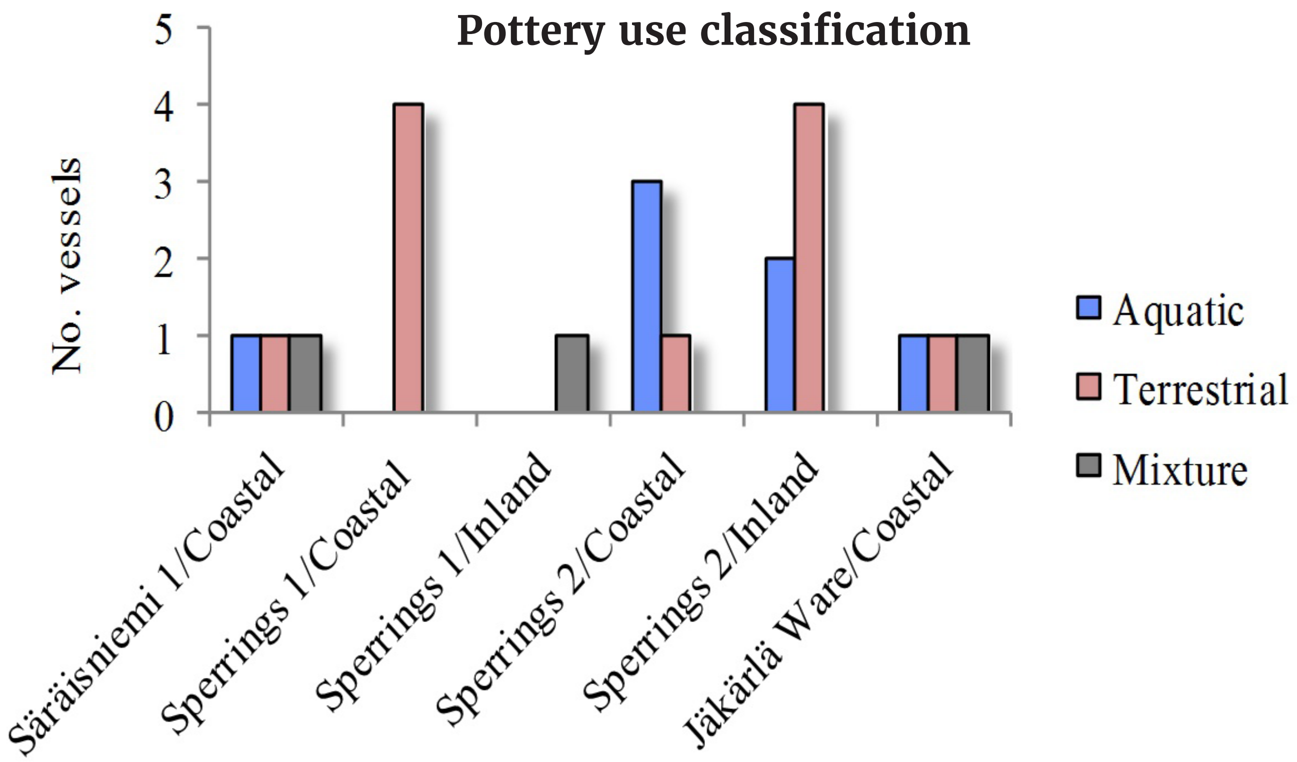

Figure 4. Relative representation of aquatic and terrestrial animal signals in the analyzed vessels by pottery tradition and site location.

significant lipid concentrations and persistence of compounds specific to their origin. The majority of the analyzed residues (55%) showed evidence of a vessel use most probably associated with cooking as it was inferred by the presence of compounds that form through protracted heating at high temperatures.

Moreover, we suggest that the early pottery use in Finland was not specialized for the processing of aquatic resources. Instead, aquatic and terrestrial animal resources were both identified as components in most of the analyzed vessel groups, irrespective of coastal/inland site division and pottery ware culture. Considering also the possible plant-deriving signals, it seems that site occupants were exploiting their local natural environments at the optimum of what it could give them for nourishment with pottery serving as useful implement in their nutritional habits. Our molecular evidence are in accord with the available archaeofaunal assemblages, although the relative proportions of aquatic *versus* terrestrial animal resources in the bone material and the analyzed residues differ. It is only the results from the Ka I:1 ceramics from the coastal Vantaa Etelä-Vantaa 3/Mätäoja III (Palmu) site that show a divergent feature with aquatic signals being absent from all analyzed residues, despite the site location and the predominance of seal bones in the archaeofaunal material.

Our observations are in line with those made by Pääkkönen et al. (2016) in a previous study on Finnish Early Comb Ware and Jäkärlä Ware pots from coastal sites concentrated in south-west Finland, and together challenge the idea of a generalized concept that associates the adoption of ceramics by hunter-fisher-gatherers in the Baltic region and elsewhere with practices related to intensified aquatic resource exploitation (e.g., Andersen 2008; Jordan & Zvelebil 2009; Craig et al. 2011; Craig et al. 2013; Taché & Craig 2015; Oras et al. 2017). Although this idea would apply in particular cultures and geographical regions, we argue that the uptake and use of ceramics is a more complex phenomenon that requires to be studied on a localized scale for interpretations of higher resolution. For instance, considering that the earliest, and contemporaneous to our material, ceramics in neighbouring Estonia, named Narva, were found to have had a more specialized use for the processing of aquatic resources, the results from Finland indicate most probably the existence of different motives behind the uptake of this technology in these two regions

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Endnote

1) The paper follows the Eastern European terminology where the Neolithic marks the introduction and use of ceramic vessels and is dissociated from farming.

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Appendix: Description of the sampled sites

1. Vantaa Etelä-Vantaa 3/Mätäoja III (Palmu)
Coordinates (EUREF-FIN): N 60.261247442, E 24.854878139, Z 31 m asl
Research history: Surveys 1962, 2000 (V. Lehtosalo, K. Lesell), excavations 1971–1973 (P. Purhonen, L. Väkeväinen)

The site was originally located at the ancient coast of the Littorina Sea in southern Finland, near Helsinki, and close to the Vantaanjoki River estuaries of that time. Excavations took place in the early 1970s, and besides Sperrings 1 (Early Comb Ware, Ka I:1), Morby Ware pottery from the Early Metal Period has also been found. The osteological material is composed mainly of seals, but regarding the early times of the excavation and the lack of sieving, the fish bones may possibly be underrepresented. The site has also yielded quartz, stone tools (axes, adzes, slate pendants) and a few pieces of decorated clay figurines of the so-called Paimio type. Today, there is a modern settlement at the area where the site was situated (Leskinen & Pesonen 2008).

Radiocarbon dates: Ua-32194: 5925±45 BP (-24,80‰ °13C), charred crust (Sperrings 1). One of the earliest dates of Sperrings 1 in Finland.

Osteological material (Vantaa Etelä-Vantaa 3/Mätäoja III (Palmu)):

Animal species	**No. of bone fragments**
Seals (*Phocidae*)	211
Eurasian beaver (*Castor fiber*)	1
Mountain hare (*Lepus timidus*)	3
Ducks (*Anatidae*)	2
Unidentified birds (*Aves.*)	7

2. Padasjoki Leirintäalue (campsite)
Coordinates (EUREF-FIN): N 61.36479359, E 25.29168219, Z 85 m asl
Research history: Survey 1971 (M. Huurre), excavations 1999, 2001–2002, 2006–2007, 2013 (S. Vanhatalo, N. Strandberg, K. Luoto, T. Karjalainen, P. Kouki)

The site is located by the Lake Päijänne, one of the biggest lakes in central Finland, on a woody terrain between the lake-shore and a steep rocky hill in the west. The surroundings of the site are highly aquatic but would also permit fair access to terrestrial resources. Besides Sperrings 1 (Ka I:1), the site has also yielded Sperrings 2 (Ka I:2) and Typical Comb Ware sherds. The find material consists mainly of quartz, ceramics and burnt bones. Pieces of a crucible indicate a later (Metal Period) use of the site.

Radiocarbon dates: The site has not so far been C14-dated.

Osteological material (Padasjoki Leirintäalue):

Animal species	No. of bone fragments
Moose (*Alces alces*)	5
Red fox (*Vulpes vulpes*)	1
Eurasian beaver (*Castor fiber*)	23
Pike (*Esox lucius*)	49
Perch (*Perca fluviatilis*)	15
Percid fish (*Percidae* sp.)	2
Cyprinids (*Cyprinidae*.)	14
Burbot (*Lota lota*)	2
Unidentified fish (*Teleostei*)	171

3. Espoo Kläppkärr

Coordinates (EUREF-FIN): N 60.20824798, E 24.58405355, Z 25-35 m asl

Research history: Surveys 1934, 1962, 2004 (E. Kivikoski, M. Huurre, H. Jansson), excavations 1998-1999 (J. Fast)

The site is located in southern Finland, west of Helsinki. Kläppkärr lies near the type site of Sperrings, on the shore of a former Littorina Sea bay. Today, it is partly located at an open land area and woodland. There have been small-scale excavations at the site in the 2000s. The find material includes Sperrings 2 (Ka I:2) and Corded Ware ceramics. The stone tool inventory is composed of a series of axes, adzes, a slate pendant and whetstones (Europaeus-Äyräpää 1930).

Radiocarbon dates: Hela-3173: 5439±43 BP (-26,00‰ δ13C), charred crust (Sperrings 2).

Osteological material: The osteological material has not so far been analyzed.

4. Lappeenranta (Etu- ja Taka-) Muntero

Coordinates (EUREF-FIN): N 61.04727687, E 28.05227743, Z 80-83 m asl

Research history: Surveys 1974, 1976, 1988, 1993, 1994, 1997, 1998, 2006, 2007, 2010, 2012 (T. Miettinen, M. Huurre, P. Pesonen, J. Luoto, T. Jussila, E. Mikkola, P. Kankkunen, J. Lagerstedt), excavations 1998, 2004, 2006-2009, 2012-2013 (J. Luoto, P. Kankkunen, E. Mikkola, P. Pesonen, T. Rostedt)

The site is located on the shore of a small pond that was formerly part of the Ancient Lake Saimaa. Lake Saimaa was the largest inland water body in Holocene Finland. The site has yielded material from several periods of the Stone Age, e.g., Sperrings 1 Ware (Ka 1:1), Sperrings 2 Ware (Ka I:2), Early Asbestos Ware and Typical Comb Ware. There have been small-scale excavations between 1998 and

2013, of which the latest was the largest so far. This excavation concentrated on the Sperrings 2/Early Asbestos Ware phase of the site, and yielded a mass of ceramics and burnt bones with some quartz material. The sampled sherds are from this phase of the excavations.

Radiocarbon dates: Hela-2231: 164±30 BP (-25,50‰ δ13C), charcoal, irrelevant date; Hela-2232: 1077+/-30 BP (-26,70‰ δ13C), charcoal, irrelevant date; Hela-2295: 5818+/-41 BP (-26,20‰ δ13C), burnt bone (meso mammal), connected with the Sperrings 1 (Ka I:1) phase of the site; Hela-2296: 5783+/-39 BP (-27,50‰ δ13C), burnt bone (mammal), connected with the Sperrings 1 (Ka I:1) phase of the site.

Osteological material: The osteological material has not been analyzed so far.

5. Oulu (formerly Ylikiiminki) Vepsänkangas
Coordinates (EUREF-FIN): N 64.99060160, E 26.22206459, Z 79 m asl
Research history: Survey 1989 (M. Mäkivuoti), excavations 1992, 1996-1998 (M. Mäkivuoti, S. Koivisto)

The vast settlement site was originally located at the north coast of the Littorina Sea, but also in close proximity to terrestrial resources. Today, it is surrounded by marshlands. Sand extraction has destroyed a big part of the site. There have been extensive excavations in the 1990s. The site is a pure Säräisniemi 1 site, at least no ceramic material from other periods has been recovered as of yet. Besides ceramics, the site has yielded stone tools, quartz, flint arrowheads (Slettnes-type), burnt bones, and pieces of "chewing resin", i.e. birch bark pitch pieces with teeth marks (Koivisto 1998; Torvinen 2000).

Radiocarbon dates: Hel-4126: 2810±90 BP (-26,70‰ δ13C), charcoal; Hel-4127: 6170±90 (-25,90‰ δ13C), charcoal; Hela-128: 5995±65 (-22,20‰ δ13C), charred crust; Hela-129: 6020±80 (-27,20‰ δ13C), "chewing resin"; Hela-235: 6065±75 (-27,50‰ δ13C), "chewing resin"; Hela-236: 6120±75 (-26,30‰ δ13C), charred crust (Säräisniemi 1 ceramics); Hela-312: 5990±60 (-27,30‰ δ13C), "chewing resin"; Hela-313: 3130±70 (-26,50‰ δ13C), charcoal. It seems that most of the charcoal datings are not related to the Stone Age settlement, while charred crust and birch bark pitch datings are well in line with each other and the Säräisniemi 1 context.

Osteological material (Oulu Vepsänkangas):

Animal species	**No. of bone fragments**
Seals (*Phocidae*.)	193
Moose (*Alces alces*)	11
Reindeer (*Rangifer tarandus*)	1
Eurasian Beaver (*Castor fiber*)	22
Mountain Hare (*Lepus timidus*)	1
Other mammals (*Mammalia* sp.)	24
Common Teal (*Anas crecca*)	13
Mallard (*Anas platyrhynchos*)	14
Eurasian Wigeon (*Anas penelope*)	8
Long-tailed duck (*Clangula hyemalis*)	4
Velvet scoter (*Melanitta fusca*)	2
Smew (*Mergus albellus*)	6
Diving ducks (*Aythya* sp.)	7
Common eider (*Somateria mollissima*)	1
Ducks (*Anatidae*)	2
Divers (*Gavia* sp.)	8
Grebes (*Podiceps* sp.)	1
Other birds (*Aves*)	47
Pike (*Esox lucius*)	68
Cyprinids (*Cyprinidae*.)	10
Unidentified fish (*Teleostei*)	75

6. Raasepori Telegrafberget
Coordinates (EUREF-FIN): N 60.01547696, E 23.68625724, Z 29 m asl
Research history: Survey 1999 (J. Fast), excavation 2001 (J. Fast)

The site is located at the southern coast of Finland in a Littorina Sea bay. There has been only a small test excavation at the site, and it may well be that most of it has been destroyed due to sand extracting. The ceramics found are exclusively of the Jäkärlä Ware type accompanied with quartz lithics.

Radiocarbon dates: Hela-3168: 5211±40 BP (-26,80‰ δ13C), charred crust (Jäkärlä Ware), one of the few crust dates produced from Jäkärlä Ware contexts.

Osteological material: The osteological material has not so far been analyzed.

Changing perspectives

Thin section and ICP analysis of Neolithic pottery from the Åland Islands

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Abstract

The location of the Åland Islands in the Baltic Sea during the Neolithic period influenced its material culture and pottery traditions. This study challenges the focus on typology by examining the technical composition of the ceramic ware and its provenance. The methods used are ICP analysis (Inductively Coupled Plasma Analysis) and analysis of thin sections of the clay used. The study includes Early and Late Comb Ware, Jettböle I and II type of Swedish Pitted Ware and Kiukais Ware. Some sherds, interpreted as combining influences from both Comb and Pitted Wares, and representing the transition from one to the other, display a reinforcement of earlier pottery traditions. The thin section analysis indicates a local technological continuity in the pottery traditions visible in the preferred clay. A chronological difference in the choice and handling of the temper suggests different preferences within traditions. The ICP analysis indicates that some of the artefacts, for example, a clay figurine seems to be of non-Åland origin.

Keywords: ceramics, thin section analysis, ICP analysis, Neolithic, Åland

Introduction

The aim of this study is to investigate the composition of pottery and its change over time as well as the provenance of the clay used in Neolithic ceramics from the Åland Islands. The results are then compared with contemporary materials from the mid-eastern part of Sweden. Methods used are thin sections and ICP analysis on sherds. The material consists of samples from different pottery traditions on the Åland Islands, from the oldest Early Comb Ware (from ca. 5500 BC), through the Late Comb Ware and the Pitted Ware to the late Neolithic Kiukais Ware (up to ca. 1800 BC).

The Åland Islands consist of a cluster of islands located between mainland Finland and Sweden. The islands have been important in prehistoric as well as historic times for the movement and cultural contacts of people from the eastern and western parts of the Nordic countries. Earlier research on Neolithic pottery from the Åland Islands has to a high degree concentrated on similarities in style in pottery traditions from mainland Finland and Sweden. This study however does not focus on style but on the technical composition of the ceramics and its provenance. The results will be compared chronologically with the changes in style.

Neolithic ceramic record of the Åland Islands

The earliest settlements on the Åland Islands are found in the valley of Långbergsöda in the municipality of Saltvik. At the time, the Åland Islands consisted of only a few small islands far from the Finnish mainland and the sites can be characterized as temporary seasonal dwellings in a maritime environment. The ceramics from these settlements are classified as older Early Comb Ware (Ka I:1). Dating of material from the sites has given values in between 5500 and 4350 cal BC (Hallgren 2008: 63; Helminen & Lucenius 2014: 6). The oldest dating from food crust on pottery is from Östra Jansmyra (Hallgren 2008: 63) in Långbergsöda. Ceramics defined as Typical (Ka II) as well as Late Comb Ware (III) occur on the Åland Islands but relatively few sites of this type are known and archaeologically investigated, except for the Late Comb Ware sites in Jomala municipality from which ceramics are included and analyzed in this study (see below). Comb Ware sites occur in the Finnish mainland dating from around 5200 BC and the Early Comb Ware represents the oldest pottery in the country together with the northern Säräisniemi 1 Ware (Leskinen & Pesonen 2009: 75–6; Halinen 2015: 56). Typologically and chronologically the Comb Ware during the Neolithic is divided into a number of subtypes, but the relevance of the traditional typological style sequences has been debated in later research (for a comprehensive discussion, see Nordqvist & Mökkönen 2015).

Pitted Ware appears on the Åland Islands around 3400/3300 BC (Stenbäck 2003). The Pitted Ware Culture is usually considered a distinct maritime hunter-gatherer culture that predominantly appears on sites in the eastern part of south and mid Sweden, although Pitted Ware is also found along the Swedish west coast and in Scania, and Denmark. On the Åland Islands the Pitted Ware phase has been labelled Jettböle I and II respectively, after the older and younger phase at the Jettböle site in the municipality of Jomala (see Cederhvarf 1912). The ceramics from the older Jettböle I phase have great similarities with the Säter/Fagervik III-style in Sweden and the younger Jettböle II-style with Säter/Fagervik IV (Meinander 1957).

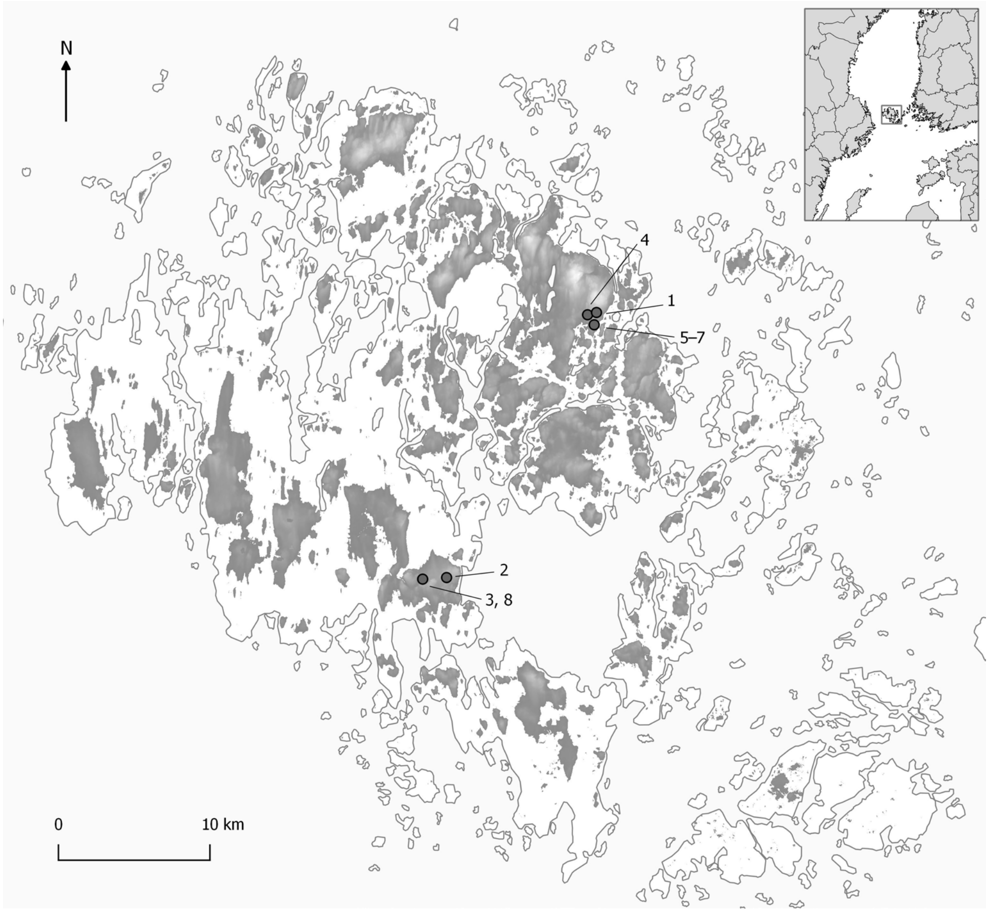

Figure 1. Map of the Åland Islands. Scale 1:500 000.

1. Sa 20.10 Vargstensslätten,
2. Jo 37.1 Stockmyra,
3. Jo 14.1 Jettböle Bergmanstorp,
4. Sa 20.7 Alkärr,
5. Sa 20.8 Glamilders,
6. Sa 20.8 Svinvallen,
7. Sa 20.8 Myrsbacka I,
8. Sa 14.1 Jettböle I and II.
(ÅLR/Museibyrån 2015).

The contour indicates the Åland Islands today and the grey area indicates the height above sea level between 20 and 130 meters. Map: Lantmäteriverket 2013/ © EuroGeographics for the administrative boundaries. Layout Mikko Helminen.

During the late Neolithic, i.e. the period ca. 2300–1700 BC, a pottery style that traditionally is classified as Kiukais Ware appears on the Åland Islands. Kiukais Ware occurs along with Pitted Ware at Svinvallen in the village of Långbergsöda in Saltvik, where sites with solely pottery of Kiukais type also are found. The Kiukais Culture is a coastal tradition found in southern and southwestern Finland (Meinander 1954; Edgren 1993; Asplund 2008: 67; Halinen 2015: 68). Within the Finnish tradition of research the Kiukais tradition has partly been defined in a similar way as the Pitted Ware tradition in Sweden; as a continuation of the traditional maritime lifestyle in a progressively more Neolithic environment (see e.g., Halinen 2015: 68).

However, there are indications of cultivated plants within the Kiukais tradition in Finland (Leskinen & Pesonen 2009: 218), as well as within the Pitted Ware tradition on the Åland Islands and on the Swedish mainland (Edenmo & Heimdahl 2012). A grain of barley, hordeum nudum, from the Pitted Ware site Glamilders, has been dated to 2880–2610 cal BC (Ua- 35045) (Possnert 2007; see also Engelmark et al. 2004). The decoration of the Kiukais Ware and the vessel shapes have great similarities with some late Neolithic pottery identified in Sweden, in Uppland and along the coast of Norrland (see Holm et al. 1997; Holm 2006).

Material and aims of the study

The main question of this study is if there is a common tradition, technological or material, within the potter's craft between the Neolithic pottery traditions on the Åland Islands. If not: which factors vary? By comparing the results from the Åland Islands with analysis performed on Neolithic ceramics from the mid-eastern part of Sweden, the aim is to broaden the perspective and understanding of the connections and contacts in the northwestern Baltic area during the Neolithic period. At present, there are no studies made on Neolithic ceramics from Finland within the area of this study, but this will be done at a later stage to make further comparisons possible. Some technological analyses are currently being done on Finnish Neolithic ceramics as new methods are introduced, and future projects are initiated (Holmqvist-Saukkonen 2012: 42).

25 sherds from seven different Neolithic sites on the Åland Islands were selected for this study. (Table 1). The method of selection was to choose samples representative of the majority of the material, i. e. not be deviant sherds. Based on traditional typology the sherds have been classified as Early (Ka I:1) and Late Comb Ware (Ka III), older (Jettböle I) and younger (Jettböle II) Pitted Ware and Kiukais Ware. Some of the sherds are difficult to classify and are interpreted as a mixed type of Comb Ware and Pitted Ware. This is especially noticeable at Jettböle Bergmanstorp, where some of the sherds have a typological similarity with Late Comb Ware, rather than Pitted Ware.

In addition to these 25 sherds this study includes another seven sherds from the Jettböle site. Thin section analysis was made on these sherds in 2003 by professor Anders Lindahl, Laboratory For Ceramic Research at the University of Lund, though the results have not yet been published. Two (2) of the seven sherds originated from Jettböle Bergmanstorp, two (2) from Jettböle I and three (3) from Jettböle II (see Stenbäck 2003: 215). ICP analysis has not been made on these sherds but the results of the thin section analyses are an important contribution to this study.

The study of the ceramics from the Åland Islands thereby contains in total 32 sherds from 8 sites (Figure 1). These 25 plus 7 sherds have been selected as representing the common type of sherds, both in decoration (common features of decoration and traditional typology) and ware, found on the selected sites (see Figure 2a-c for photographs of the sherds). The selection of samples from each site has been made ocularly. The idea is to establish a basic understanding of the diversity or conformity of the ware and the craft used, as a starting point for the discussion of continuity or change in the represented pottery traditions.

In terms of style the pottery from Vargstensslätten has been classified as older Early Comb Ware (Ka I:1) (Väkeväinen 1975b; 1978) but the pottery is not entirely homogeneous. Ocular evaluation suggests the samples consists of two different types of ceramics, a very coarse grained black fabric tempered with quartz, and a finer red fabric tempered with rock. A previous diatom study of contemporary ceramics with a similar coarse-grained fabric from the nearby site Sa 20.2 Östra Jansmyra (not included in this study), concluded that the constitution of diatoms in the clay indicate that the vessels were made of Ancylus transgressional sediments or clay (see Haavisto-Hyvärinen & Kutvonen 2007), which supposedly was not available on the Åland Islands during the relevant period (Glückert 1978; Alhonen & Väkeväinen 1980: 745). Thus, the pottery was interpreted as imported to the islands from mainland Finland. Among the ceramics from Östra Jansmyra, clay with a content that indicated the use of a locally accessible plastic *gyttja* was observed. (Alhonen & Väkeväinen 1980: 74–5).

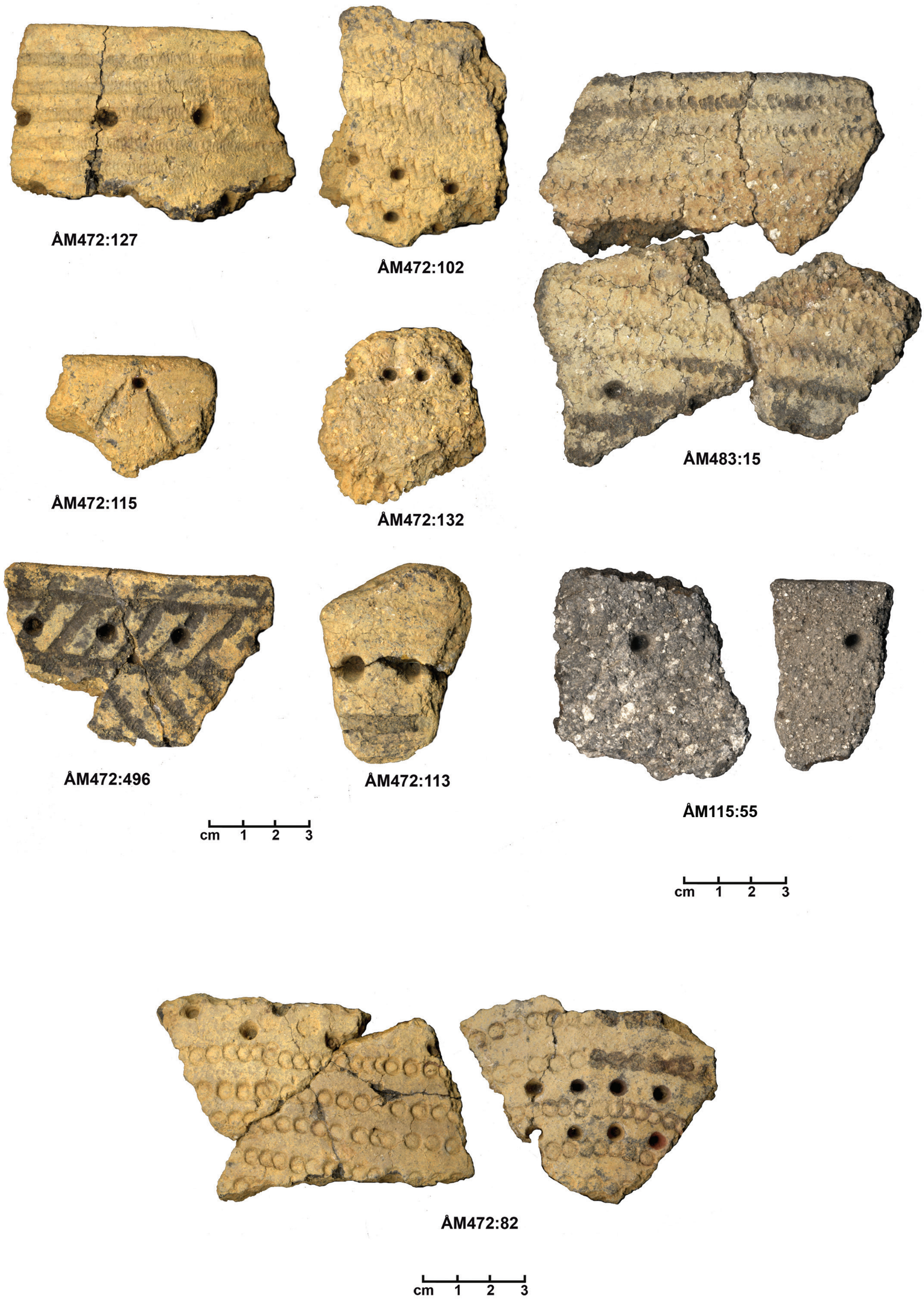

Figure 2a. The analyzed ceramics from the site 1. Vargstensslätten, Sa 20.10 (ÅM 115, 472, 483). Photo and adaption: Daniela Stenbäck.

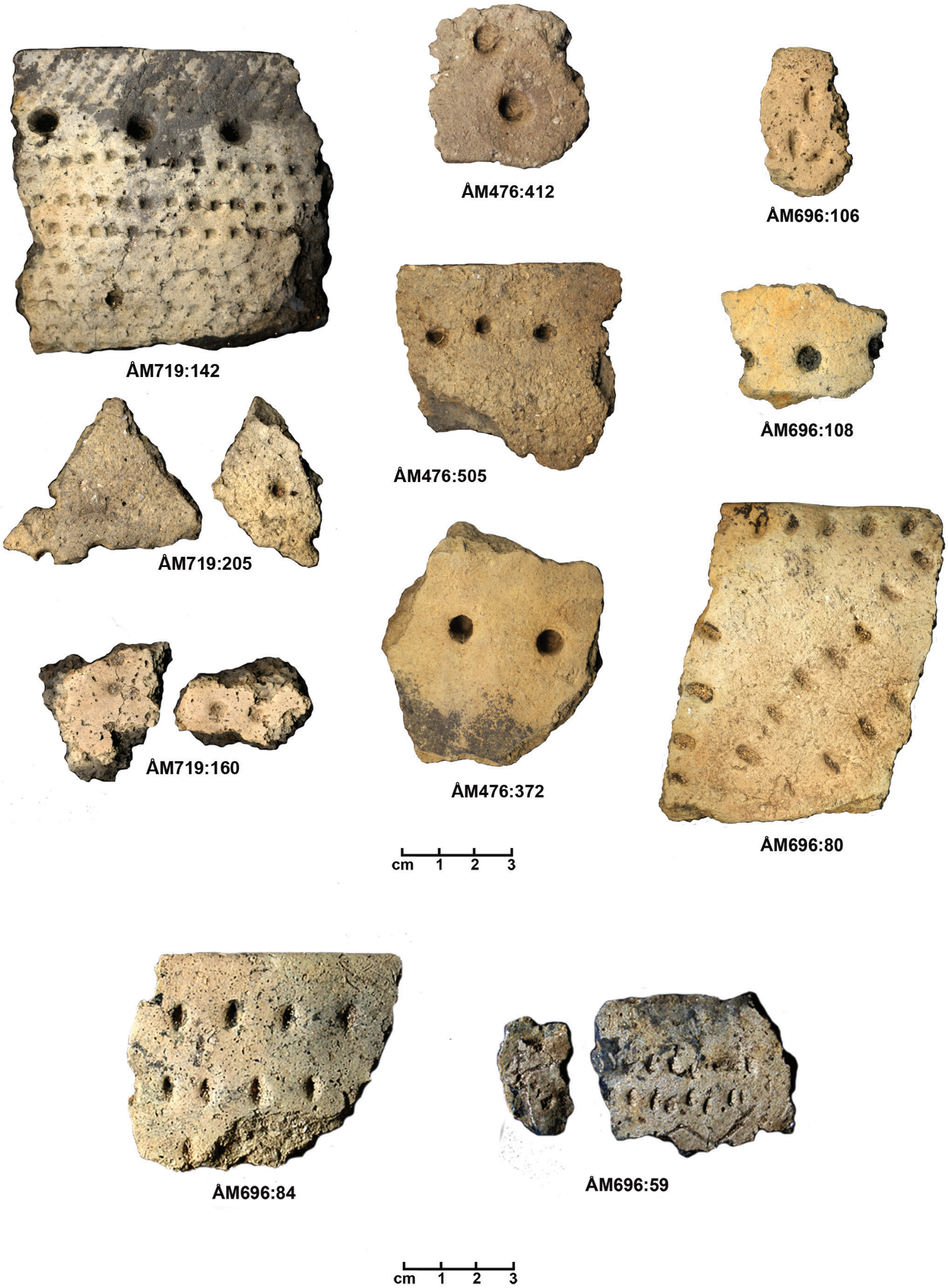

Figure 2b. The analyzed ceramics from the sites 2–4. Stockmyra, Jo 37.1 (ÅM 719), Alkärr, Sa 20.7 ÅM (476), Jettböle Bergmanstorp, Jo 14.1 (ÅM 696). Photo and adaption: Daniela Stenbäck.

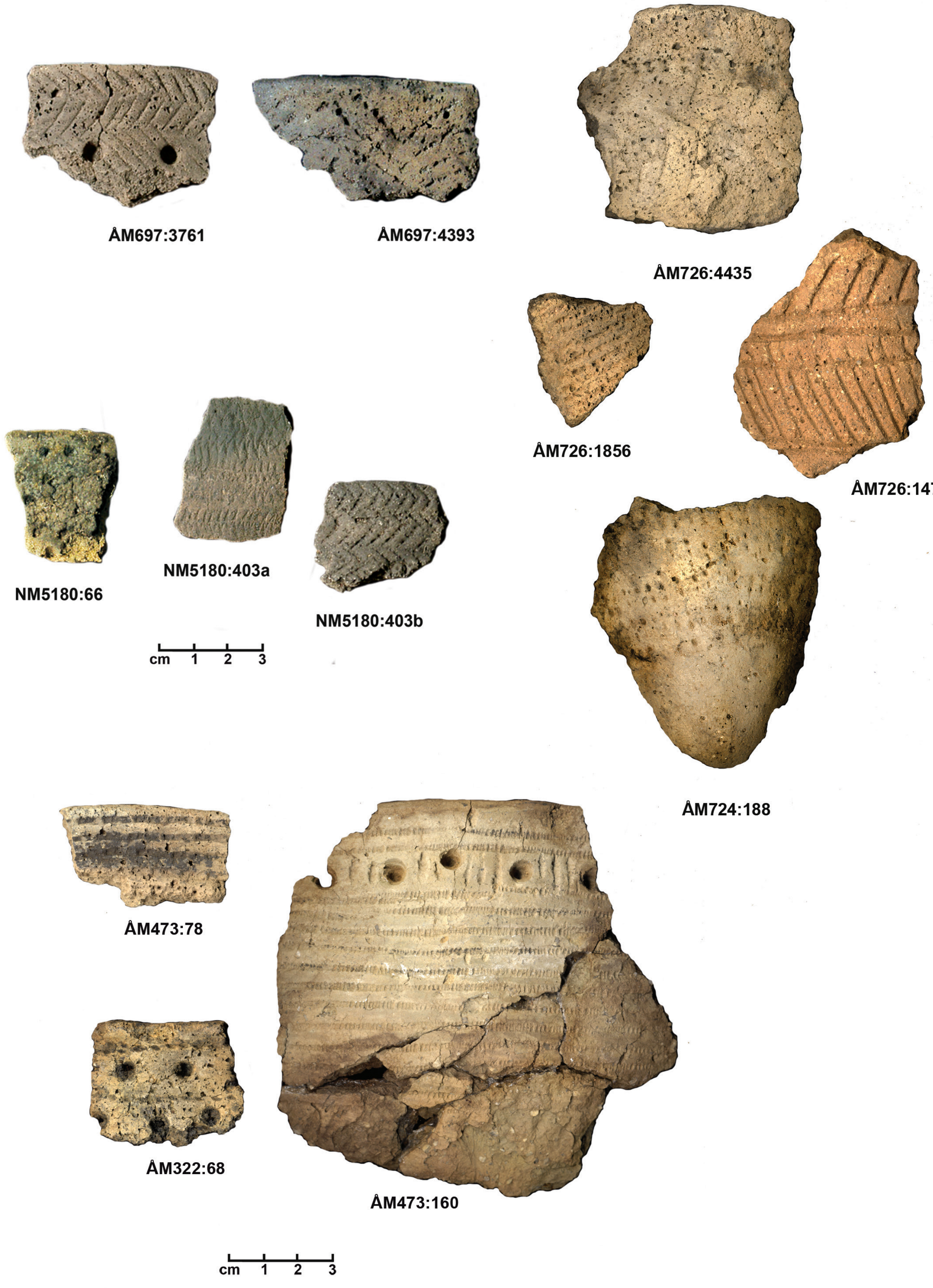

Figure 2c. The analyzed ceramics from the sites 5–8. Glamilders, Sa 20.8 (ÅM 724, 726), Svinvallen Sa 20.8 (ÅM 473), Myrsbacka, Sa 20.8 (ÅM 322), Jettböle I (ÅM 697) Jettböle II, Jo 14.1 (NM 5180). Photo and adaption: Daniela Stenbäck.

Only a few sites with Typical and Late Comb Ware have been found on the Åland Islands. One of them is Stockmyra site, investigated in the 1940's and in the beginning of this century. The ceramics have been classified as Typical Comb Ware (Ka II) by Dreijer (1947; 1979) but a later excavation indicated an element of Late Comb Ware (Ka III) among the sherds (Fagerholm-Sjöblom 2002). Typologically the ceramics from this site is distinct Comb Ware, and there is no indication of presence of Pitted Ware.

Jettböle Bergmanstorp is situated close to the famous Pitted Ware Jettböle site, but on a slightly higher level in the landscape, not far from the Stockmyra site. In the archaeological excavation at Bergmanstorp in 1999 older Pitted Ware, Late Comb Ware as well as ceramics that were difficult to classify were found. Some sherds were impossible to interpret typologically as being either Comb Ware or Pitted Ware. Based on this it has been suggested that Jettböle Bergmanstorp may represent an earlier phase of settlement and a typological transition or mixed phase between Comb and Pitted Ware (Stenbäck 2003). Four out of the five analyzed sherds from Bergmanstorp have been typologically classified as Comb Ware or similar to this type. The fifth sherd is difficult to classify.

Alkärr is, as the above-mentioned site Vargstens-slätten, situated within the Långbergsöda area, but on a significant lower level in the landscape. The ceramics from Alkärr has been classified partly as Late Comb Ware (Ka III) and partly as older Pitted Ware (Väkeväinen 1975a). Alkärr and the nearby Comb Ware site Tisdal together represent the succession between Comb- and Pitted Ware in the Långbergsöda area (Stenbäck 2003). Two of the analyzed sherds from Alkärr have been typologically classified as Late Comb Ware or a mixed form of Comb and Pitted Ware, and one sherd as older Pitted Ware, although this sherd is typologically difficult to classify.

Compared to Alkärr, the site Glamilders is situated at a lower level in the landscape in the Långbergsöda area. The ceramic assemblage from Glamilders has principally been classified as younger Pitted Ware, but with some typological elements of older Pitted Ware. In this case, younger Pitted Ware relates to the Jettböle II phase on the Åland Islands or the Säter/Fagervik IV phase in Sweden (Meinander 1957; Stenbäck 2003). Three sherds and a fragment of a clay idol are included in the analysis (for discussion on clay idols, see Nuñez 1987).

Svinvallen and Myrsbacka are both situated just below Glamilders and the three sites form a chronological sequence; Pitted Ware during the Middle Neolithic, then to Kiukais Ware during late Neolithic and early Bronze Age. The assemblage from Svinvallen contains both younger Pitted Ware and Kiukais Ware, while Myrsbacka I and II contains Kiukais Ware and Bronze Age ceramics respectively (Meinander 1984).

The site of Jettböle I-II is situated just below Bergmanstorp and was investigated in the early 1900s by Björn Cederhvarf (1912). He divided the site into an upper, older part and a lower, younger part, referred to as Jettböle I and II respectively, based on differences in ceramic styles between the two areas. Cederhvarf excavated the Jettböle site at the same time as among others Oscar Almgren (1906; 1912) had found and investigated Pitted Ware settlements in Uppland and mid-eastern Sweden. The ceramics from Jettböle I and II were interpreted as having similarities with Säter/

Fagervik III and Säter/Fagervik IV respectively (Meinander 1957; Stenbäck 2003: 184). The Jettböle site, including Jettböle Bergmanstorp, was excavated in 1999-2000, and a number of 14C dating confirm that the older Jettböle I phase can be dated to Middle Neolithic A (3300–2800 BC) and the Jettböle II phase to Middle Neolithic B (2800–2300 BC), referring to the periodization used in Sweden (Stenbäck 2003).

Methods

Two different methods for analyzing ceramics have been used in this study, thin section analysis and ICP analysis. It is a combination of microscopy of the fabric, which is used to determine the type of raw materials used in the ceramics, and ICP analysis, which is a method based on geochemistry where samples are analyzed by mass spectrometry. The ceramic terminology customary at The Laboratory for Ceramic Research at Lund University is used in this article (see e.g., Hulthén 1977).

Studies of Neolithic pottery has been dominated above all by questions on typologies and style, and these have in several respects formed the most important tools in the discussions on the cultural affiliations of the pottery traditions. At an early research stage, it was observed that both Comb Ware and Pitted Ware with a porous fabric originating from a temper rich in calcareous material existed. As a consequence, the quality of the fabric has been central in the discussions on both Early and Late Comb Ware as well as the Säter-/Fagervik sequences within the Pitted Ware tradition. (see e.g., Edenmo et al. 1997; Nordqvist & Mökkönen 2015). The Early Comb Ware (Ka I:1) generally lack calcareous material temper while the Late Comb Ware (Ka III) has limestone or shell in the temper (see e.g., Edgren 1993; Leskinen & Pesonen 2009: 82). The aim of this study is primarily to investigate whether any changes in the production of pottery occurred from Comb Ware to Pitted Ware and Kiukais Ware on the Åland Islands. We know that the presence of calcareous material is a factor in a changing/variable craft, but it is also possible that the choice of clay and parts of the temper may have changed over time. Both choice of type of temper and the amount of temper can be related to the different types of wares.

To study the types of temper and clay, analysis by means of ceramic thin sections has been carried out. The thin section analysis was performed with slides of a total of 32 (25 plus 7 – see above) different sherds from the Åland Islands (Table 1) in a polarization microscope. During the analysis type of clay, type of temper and part of volume, largest grain, mineralogical composition and presence of any diatoms can be determined. Thin section analysis has been used in Scandinavia since the 1930s and it can be considered a well-established method for studying pottery (Bøe 1931; Hulthén 1977; Brorsson 2008b; Quinn 2013; for further discussion see Holmqvist-Saukkonen 2012). It is important to note that a thin section analysis is not only a petrographic analysis, it also covers the whole fabric, including vessel building technique and temper of other material than rocks, etc.

The thin section analysis has been combined with ICP analysis (ICP-MA/ES), in order to study if the pottery has been manufactured on the same site or not. ICP-MA/ES is a method which can be classified as instrumental geochemistry and it allowed us to determine the presence of 44

Table 1. Sites included in this study.

Site (prehistoric settlement)	Masl	^{14}C-datings	Ceramic style	Number of sherds	References
1. Vargstensslätten (Sa 20.10)	c 55	5310-4650 BC*	Early Comb	9	Väkeväinen 1978, Hallgren 2008: 63*
2. Stockmyra (Jo 37.1)	c 44		Late Comb	3	Dreijer 1947, Fagerholm-Sjöblom 2002
3. Jettböle Bergmanstorp (Jo 14.1)	c 40	3550-2880 BC*	Late Comb / older Pitted Ware	3 + 2	Stenbäck 2003:181f*
4. Alkärr (Sa 20.7)	c 40		Late Comb / older Pitted Ware	3	Väkeväinen 1975
5. Glamilders (Sa 20.8)	c 35	2880-2610 BC*	Younger Pitted Ware	4	Meinander 1957, Vaara 2004*
6. Svinvallen (Sa 20.8)	c 32		Kiukais	2	Meinander 1984
7. Myrsbacka I (Sa 20.8)	c 32	2350-1940 BC*	Kiukais	1	Meinander 1984, Holm 2006:149*
8a. Jettböle I (Jo 14.1)	c 35	3360-2620 BC*	Older Pitted Ware	2	Cederhvarf 1912, Storå & Stenbäck 2001*
8b. Jettböle II (Jo 14.1)	c 30	2890-2200 BC*	Younger Pitted Ware	3	Cederhvarf 1912, Storå et al 2002*

non-organic elements, which were subsequently used to place the samples into distinct chemical groups. A minimum of 0.5 g of sample was ground into a fine powder and then dissolved in acid solution. The solution was then injected into excited argon plasma and when the atoms were targeted with massive energy, the electrons produced coloured rays, unique for every single element. The spectrum of atomic emission was measured subsequently with AES. From the 44 elements measured, 12 were used for data processing. The selection was based on previous experience of reliable discriminating elements in clay and pottery and chosen to include a wide cross-section of chemically different elements. These were the post-transition metals aluminium (Al), chromium (Cr), gallium (Ga), manganese (Mn) and vanadium (V), the alkaline earth metals calcium (Ca), magnesium (Mg), strontium (Sr), the lanthanides cerium (Ce) and lanthanum (La), the alkaline metal sodium (Na) and the transition metal cobalt (Co). The large amount of data was processed using the SPSS statistical software package for cluster analysis of the elemental dataset. Furthermore, the content of calcium (Ca) was determined, which can contribute to the discussion on possible use of calcareous material as temper. The method is rather well established in European archaeology. Already in the 1990's Alan Vince, Lincoln, UK (e.g., Vince 1999), began to perform ICP analyses of Prehistoric and Historic pottery in Northern Europe and the method is today frequently used on pottery in several North European countries.

Thin section analysis

The results of the thin section analyses are presented according to the type of clay and the choice of temper material. This is because the aim is to examine the composition of fabrics within the traditionally pre-defined pottery types to enable comparisons, and initiate a discussion on ceramic technology with a changed perspective from typology to technology and its changes over time. (Figure 3).

Type of clay

The clays have according to the presence of silt and sand been divided into fine, medium coarse and coarse. All but one, a sherd from Alkärr (ÅM476:372), of the 32 analyzed sherds consists of sorted fine clay. A sorted fine clay has small

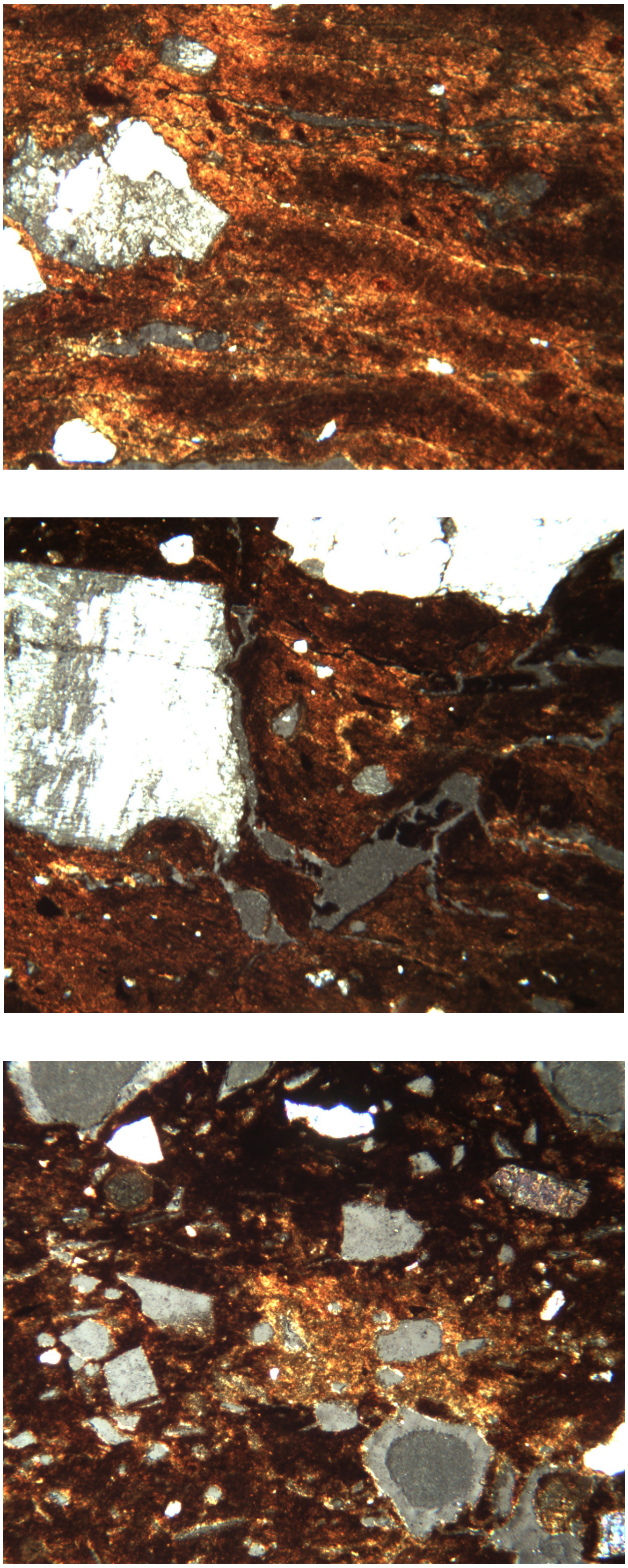

Figure 3. Thin sections. Photos taken in microscope, 40 x. Thin section 3 from Vargstensslätten (ÅM472:102) tempered with crushed quartz. Thin section 11 from Stockmyra (ÅM719:205) with quartz and limestone. Thin section 22 (the idol) from Glamilders (ÅM726:1856) only with limestone. Photo: Torbjörn Brorsson.

amounts or no silt at all. Of these 31 clays, all, except two from Alkärr (ÅM476:412, 505) and one from Jettböle Bergmanstorp (ÅM696:84), were very dense and lacked element of both silt and sand. Thus, it is worth noting that the same type of clay has been used on all sites, except Alkärr and Jettböle Bergmanstorp. The three deviating fine clays from Alkärr and Jettböle Bergmanstorp were silty, but still the quality of the clay was fine. The only sherd with a completely different fabric was a probable Pitted Ware sherd from Alkärr, number 18 (ÅM476:372). Even though the fabric appears to consist of a coarse sandy and silty, unsorted clay, calcareous material has been identified within the clay. The content of calcareous material may be natural. It can be determined that there is no difference in choice of clay between the different types of ceramics or between all the sites, except Alkärr (see below). (Table 2).

Tempering with crushed rock only – quartz

The fine clays have in 17 of the analyzed sherds been tempered with crushed quartz. In one of the thin sections from Jettböle II (NM5180:66) possible grains of diabase or gabbro have been observed, but this does not affect the interpretation of the provenance of the vessels. The maximum grain size varies between 1.5 and 4.5 mm, which indicates that the tempering has been handled in different ways and furthermore the temper has been sieved in several cases before it was added to the clay. The sieved temper consists of grains in the same hiatus, which is about 2.0 to 4.0 mm and no smaller grains have been identified. All nine analyzed Early Comb Ware sherds are found in this group of clay tempered with quartz. The same applies for two out of three sherds from Alkärr (ÅM476:412, 505) and three out of four from Jettböle Bergmanstorp (ÅM696:59, 80,108),

Table 2. Results of thin section analysis from the Åland Islands. n.o. = not observed. X = presence. n.i.= no information. Samples 1–25 analyzed by Torbjörn Brorsson, samples J1-J7 by Anders Lindahl.

Thin section	ÅM	Find no.	Site	Sorted / Unsorted	Coarse / Medium / Fine	Silt	Sand	Iron oxide	Mica	Calcium	Diatoms	Organic matter	Calcium	Crushed rock	Grog	Sieved	Amount of temper (%)	Maximum grain (mm)	Notes
1	115	55	Vargstensslätten	Sorted	Fine			+	-		n.o.	x		x			18	4,0	Quartz, mica, sandstone
2	472	82	Vargstensslätten	Sorted	Fine			+	-		n.o.	x		x		x	11	3,5	Quartz, mica
3	472	102	Vargstensslätten	Sorted	Fine			+	-		n.o.			x		x	10	2,5	Quartz, mica
4	472	113	Vargstensslätten	Sorted	Fine			+	-		n.o.			x		x	13	3,0	Quartz, mica, sandstone
5	472	115	Vargstensslätten	Sorted	Fine			+	-		n.o.			x		x	15	3,0	Quartz, mica
6	472	127	Vargstensslätten	Sorted	Fine			+	-		n.o.			x		x	17	4,5	Quartz, mica
7	472	132	Vargstensslätten	Sorted	Fine			+	-		n.o.			x		x	15	3,0	Quartz, mica
8	472	496	Vargstensslätten	Sorted	Fine			+	-		n.o.	x		x			28	4,5	Quartz, mica
9	719	142	Stockmyra	Sorted	Fine			+	-		n.o.		x				12	2,5	
10	719	160	Stockmyra	Sorted	Fine			+	-		n.o.		x				10	2,5	Few grains of quartz
11	719	205	Stockmyra	Sorted	Fine			+	-		n.o.		x	x		x	10	1,5	Quartz
12	483	15	Vargstensslätten	Sorted	Fine			+	-		n.o.			x			26	4,5	Quartz, mica, sandstone
13	696	80	Jettböle Bergmanstorp	Sorted	Fine			+	-		n.o.			x		x	12	2,5	Quartz, mica
14	696	106	Jettböle Bergmanstorp	Sorted	Fine			+	-		n.o.		x		x		12	2,0	Few grains of quartz
15	696	108	Jettböle Bergmanstorp	Sorted	Fine			+	-		n.o.			x			20	2,0	Quartz, mica, sandstone
16	476	412	Alkärr	Sorted	Fine	x		+	-		n.o.			x			17	4,0	Quartz. Few grains of lime
17	476	505	Alkärr	Sorted	Fine	x		+	-		n.o.			x			15	1,5	Quartz
18	476	372	Alkärr	Unsorted	Coarse	x	x	+	-		n.o.							1,5	Rich in calcium
19	724	188	Glamilders	Sorted	Fine			+	+		n.o.		x				22	1,5	Few grains of quartz
20	726	1472	Glamilders	Sorted	Fine			+	-		n.o.		x	x			17	2,0	Quartz. Low amount of calcium
21	726	4435	Glamilders	Sorted	Fine			+	-		n.o.		x				25	2,0	Few grains of quartz
22	726	1856	Glamilders	Sorted	Fine			+	-		n.o.	x	x				27	1,0	
23	473	78	Svinvallen	Sorted	Fine			+	-		n.o.		x				19	1,0	Few grains of quartz
24	473	160	Svinvallen	Sorted	Fine			+	-		n.o.			x		x	12	3,5	Quartz, mica
25	322	68	Myrsbacka	Sorted	Fine			+	*		n.o.		x				21	2,0	Few grains of quartz
J1	696	59	Jettböle Bergmanstorp	Sorted	Fine			+			n.o.			x			e.u.	3,0	
J2	696	84	Jettböle Bergmanstorp	Sorted	Fine	x		+			n.o.		x	x			e.u.	1,5	Quartz, sandstone. Quartz?
J3	697	3761	Jettböle I	Sorted	Fine			+			n.o.		x				e.u.	2,0	
J4	697	4393	Jettböle I	Sorted	Fine			+			n.o.		x				e.u.	2,0	
J5	5180	66	Jettböle II	Sorted	Fine			+			n.o.			x			e.u.	2,0	
J6	5180	403A	Jettböle II	Sorted	Fine			+			n.o.			x			e.u.	1,5	
J7	5180	403B	Jettböle II	Sorted	Fine			+			n.o.		x				e.u.	2,0	

as well as two out of three sherds from Jettböle II (NM5180:66, 403A). Noticeable is that the sherds from Alkärr and Jettböle Bergmanstorp have been interpreted as Late Comb Ware or a mixed form between Comb Ware and Pitted Ware. One sherd from Svinvallen belongs to the clays that have been tempered with quartz and this sherd belongs to the Kiukais culture. Further it can be verified that the sherds with the largest grain of rock are found in this group and eight out of nine sherds from Vargstensslätten have a largest grain size of 3.0 mm. The same is valid for one sherd from Alkärr, one from Jettböle Bergmanstorp as well as one from Svinvallen. The amount of temper in these 14 sherds varies between 10 and 28 % (percent in volume calculated under the microscope), which indicates a partially different fabric. The variation within the material from Vargstensslätten may have been related to the function of the vessels, or due to some other reason. Thin section number 2, 3 and 13 had the smallest amount of temper while thin section number 8 and 12 had the largest amount. Generally, it can be stated that the sherds belonging to vessels manufactured from clays tempered with crushed quartz contained large grain of temper, often larger than 3.0 mm in diameter.

Tempering solely with material rich in calcareous material

From all of the sites except the oldest in this study, Vargstensslätten and Alkärr, ceramics with tempering of calcareous material alone have been found. Two of the three analyzed sherds from Stockmyra (ÅM719:142, 160), determined as Late Comb Ware, are found in this group. Three out of four Pitted Ware sherds from Glamilders (ÅM724:188, ÅM726:4435, 1856), two Early Pitted Ware sherds from Jettböle I (ÅM697:3761, 4393), one of the three younger Pitted Ware sherds from Jettböle II (ÅM403B) as well as the Kiukais Ware from Svinvallen and Myrsbacka (ÅM473:78, ÅM322:68), falls into the same group. One out of five sherds from Jettböle Bergmanstorp (ÅM696: 106), that has been classified as Late Comb Ware, also contained temper rich in calcareous material. In this ceramics, small amounts of grog have also been identified. The use of grog occurs within the Comb Ware tradition on the Finnish mainland (Leskinen & Pesonen 2009: 170). The sherd from Jettböle Bergmanstorp was decorated with imprints of fingernails and the fabric was very porous.

Unlike the fabric with crushed rock, the grains of rock were not as large in the fabrics rich in calcareous material. Isolated grains of quartz, between 1.0 and 2.5 mm occurred. The largest grains (2.5 mm) were found in the Late Comb Ware from Stockmyra. A refinement in grain size is noticeable from the Early to the Late Comb Ware. Generally, the amount of temper was high; from 19 to 27 %, and it constitutes a large part of the fabric. In three sherds, however, the temper was between 10 and 12 %, and these sherds originated from Stockmyra (ÅM719:142, 160) and Jettböle Bergmanstorp (ÅM696:106).

It is interesting to conclude that the Late Comb Ware from Stockmyra contained temper of calcareous material, although in relatively low amounts. This is the earliest indication of clay tempered with calcareous material on the Åland Islands. The rest of the ceramics with high amounts of calcareous material temper have been interpreted as Pitted Ware and Kiukais Ware.

The analysis has not confirmed what type of material rich in calcareous material that has been added to the fine clays. However, the form of the pores makes it unlikely to be bone, more probable the temper consists of limestone or possibly shell. The bedrock on the Åland Islands, as in other parts of the Baltic area, consists of quartz porphyritic rapakivi granite, Pyterlite and in the Långbergsöda area also Viborgite. The soil types represented are gravel/sand moraine, fine moraine, sand and clay. (Geological Survey of Finland (GTK); Haavisto-Hyvärinen & Kutvonen 2007). It has not at this stage been possible to use mineralogy to determine the provenance of the vessels.

The amount of grog in thin section 14 (ÅM696:106) from the sherd from Jettböle Bergmanstorp is so small that it does not influence the function of the vessel, nor is it likely to represent a different ware. Probably there were other reasons why the grog was added to the clay. The tempering could have had a symbolic function as a link to the past (Larsson 2009: 352).

Tempering with crushed quartz and material rich in calcium

One sherd from Stockmyra (ÅM719:205), one from Glamilders (ÅM726:1472) as well as one from Jettböle Bergmanstorp (ÅM696:84) are all very similar. These have been manufactured of fine clays tempered with crushed quartz and materials rich in calcareous material. The amount of temper in the sherds from Stockmyra and Glamilders are 10 and 17 % respectively and the largest grains of rock has been measured to 1.5 and 2.0 mm. The two sherds have been interpreted as Late Comb Ware and Younger Pitted Ware respectively. The sherd from Jettböle Bergmanstorp is interpreted as Late Comb Ware.

Naturally sandy/silty clay

One sherd from Alkärr (ÅM476:372) has been described as an unsorted sandy and silty coarse clay. It means that no temper was added and that the clay was considered coarse enough for its purpose and this has been classified as natural sand/silt tempered. All the mineral grains in the fabric were rounded and the hiatus was rather equable. The calcareous material found in the clay indicates that the clay was probably naturally rich in calcareous material.

ICP analysis with the aim to determine the provenance of the ceramics

With the purpose to try to answer the question where the ceramics were manufactured ICP analysis has been performed on 25 sherds from the Åland Islands (Table 3). The method is based on determining the "chemical finger print" of the sherds and among other factors, a number of trace elements are important in determining where the clays and possible temper were collected. One trace element that is used for determination is calcium (Ca), which obstructs the interpretation. Calcareous material has been added to some of the clays and thus the analysis has been performed both with and without calcareous material, with the same result.

The ICP analysis is presented as a dendrogram, which is one of the best methods to understand and visualize the relationship between different samples (Figure 4). Two samples deviate significantly from the others, sherd 22 (ÅM726:1856); the idol from Glamilders, and sherd 20 (ÅM726:1472); a Pitted Ware sherd from the same site (ÅM726:1472, 1856). They fall into two entirely separate groups and they most likely have a different provenance than the Åland Islands. The other 23 sherds fall into different groups where the sherds from Jettböle Bergmanstorp, Glamilders, Svinvallen and Stockmyra are found in the same group, while another group constitutes of four sherds that all come from Vargstensslätten. The distribution is generally large and the different groups are mixed. It seems impossible to determine if the sherds originate from vessels from specific sites of manufacture on the Åland Islands, because the method of analysis is not detailed enough. The sherds have been compared to material from Gotland, and the result is that the ceramics from the Åland Islands form its own groups without any similarities with contemporary pottery from Gotland (Brorsson 2015). The same method of analysis was used as on the Åland Islands material and one of the most significant results was that the samples from Gotland contained significantly higher amounts of natural calcium in the clays than the sherds found in The Åland Islands.

It can be stated that a large number of the analyzed sherds probably have an Ålandic origin, based on the large number of sherds with the same chemical composition (cf. Holmqvist- Saukkonen 2012: 33). The pots could of course have been made out of raw material from elsewhere, but according to the number of heterogeneous samples this seems unlikely. The homogenous material is interpreted as the remains of several Ålandic productions. Although this result is based on the assumption that the relatively large number of sherds analyzed that share the same chemical composition originate in the same region, it seems plausible to conclude this region as being the Åland Islands, representing a local craft tradition prevalent throughout the Neolithic, rather than import from neighboring regions. The homogenous character of the clay used, in relation to the differing styles in the ceramic assemblage studied from the Åland Islands, also seem to support this assumption. Vessels and items of alternative provenance are most likely also present in the investigated material. The idol from Glamilders differs so significantly in clay composition, that it most probable has a non Ålandic origin, and the same goes for the Pitted Ware sherd number 20 (ÅM726:1472). The thin section analysis of the fabric in these sherds showed that they did not deviate from the other analyzed sherds from the Åland Islands, but the ICP analysis indicates another provenance. The craftsmanship is the same, which could suggest distinct relations between the Åland Islands and the Swedish mainland.

Changes over time in the ceramics from the Åland Islands

The analysis of the fabric indicates that the ceramic craft from the Early Comb Ware and up to the Kiukais Ware changed to a relatively significant degree (Tables 4 and 5). This period covers 3000 years and it is evident how the craft changed from using a fairly coarse fabric to a smother one, and with elements of new types of temper. However, a common feature during this time is distinguished and that is the choice of clay; sorted fine clays were used. This was also the case on the Swedish mainland during the early and middle Neolithic, following the Swedish classification of periods, i. e. 4000–2300 BC.

The Early Comb Ware was manufactured from clays tempered with crushed quartz of large grain size. The temper was sieved prior to it was added to the clay, as it was done within the Scandinavian Funnel Beaker tradition (Brorsson 2008b: table 18) which occurred in mid-eastern Sweden ca. 4000 – 3300 BC (Kihlstedt et al. 1997), i. e. it was

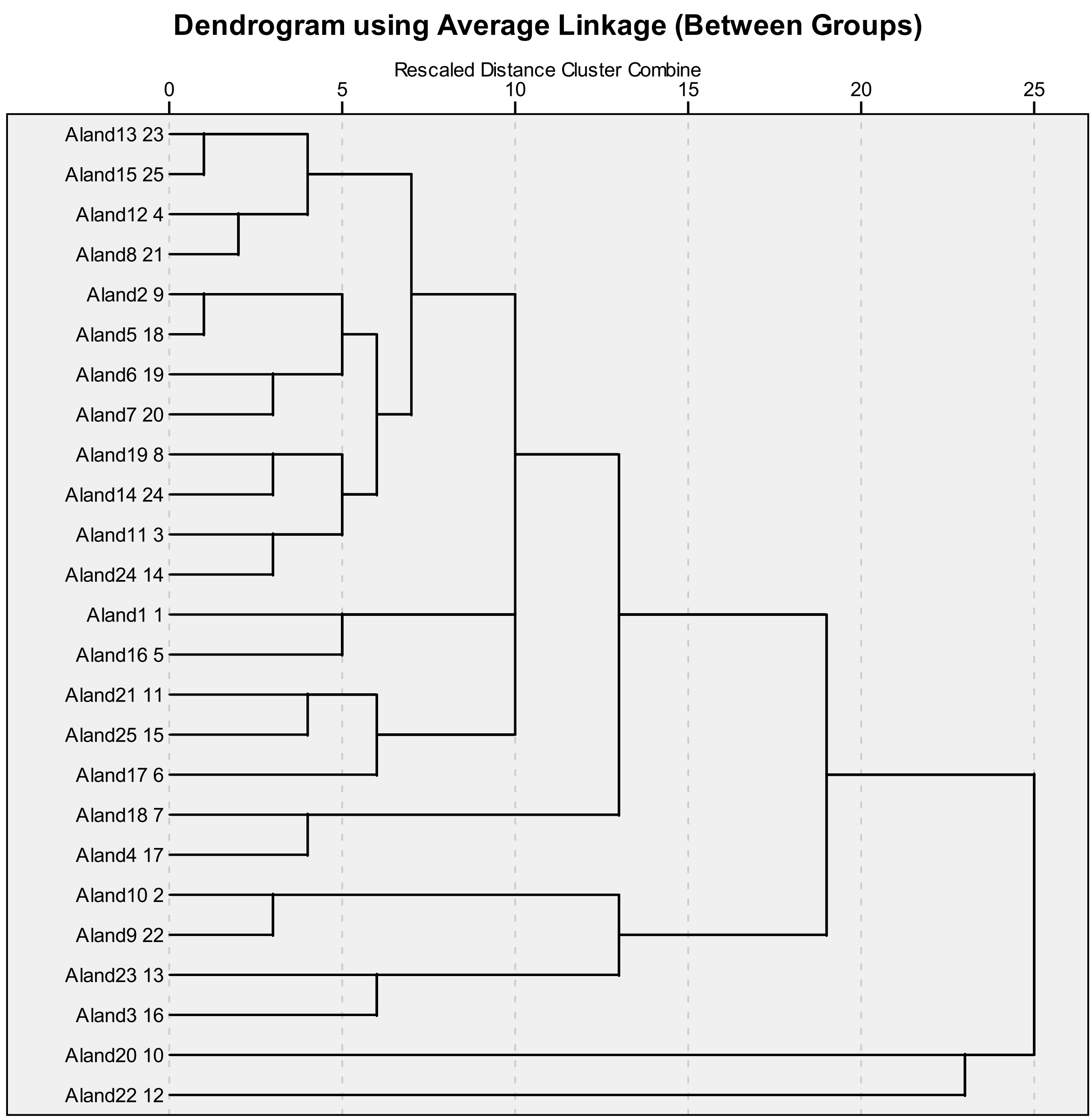

Figure 4. Dendrogram on the statistics based on ICP analysis of ceramic from the Åland Islands. The two samples at the bottom of the chart deviate significantly from the rest. Probably those two have not been manufactured on the Åland Islands. The numbers Åland 1–25 refer to the 25 analyzed sherds (compare Table 1).

Table 3. Results of the ICP analysis.

	Ag	Al	As	Ba	Be	Bi	Ca	Cd	Ce	Co	Cr	Cu	Fe	Ga	Ge	K	La	Li	Mg	Mn	Mo	Na
	ppm	%	ppm	ppm	ppm	ppm	%	ppm	ppm	ppm	ppm	ppm	%	ppm	ppm	%	ppm	ppm	%	ppm	ppm	%
Aland1	0,16	6,43	8	780	1,68	0,27	0,63	0,69	126,5	10,1	65	17,8	5,35	26,6	0,14	3,55	60,4	31,3	1,04	344	0,61	1,11
Aland2	0,08	8,33	7,9	730	3,78	0,35	1,2	0,14	128	20	101	44,7	5,73	27,1	0,13	2,82	73,3	66,3	1,53	675	0,81	1,53
Aland3	0,09	8,49	6,9	760	6,83	0,35	0,7	0,18	194	19,6	103	33,3	6,07	31,1	0,19	3,11	105	72,2	1,55	461	0,7	0,97
Aland4	0,07	8,29	2,9	810	4,6	0,22	0,82	0,13	141	13,6	79	29	4,16	23,8	0,12	3,19	83,8	56,8	1,2	347	0,35	1,51
Aland5	0,12	8,83	6,7	920	5,53	0,27	1,46	0,24	171	20,3	85	42,5	5,93	26,9	0,19	2,36	85,5	49	1,46	676	0,91	1,5
Aland6	0,07	8,44	5,4	670	5,03	0,57	0,6	0,17	151	13,8	75	22,3	4,61	26,4	0,21	3,81	77,2	74,4	1,22	404	0,52	1,24
Aland7	0,12	8,8	6,1	690	5,06	0,38	0,82	0,19	164,5	17,4	93	31,1	5,59	25,5	0,18	2,68	89,6	54,7	1,56	435	0,65	1,13
Aland8	0,12	8,24	4,4	770	3,63	0,22	1,75	0,13	110	17,5	63	27,1	5,9	23,3	0,17	2,68	54,6	54,9	1,48	687	0,7	1,51
Aland9	0,1	8,42	10,7	760	3,42	0,43	1,27	0,19	110,5	34,1	134	53,8	8,7	27,5	0,18	3,03	44,1	61,1	2,24	1390	1,29	1,03
Aland10	0,11	7,97	12,7	670	4,8	0,68	1,2	0,23	146	31,1	115	34,5	7,33	25,7	0,17	2,87	66,9	49,2	1,75	1630	1,11	0,94
Aland11	0,12	7,77	9,4	670	3,12	0,3	0,98	0,33	122	20,9	106	34,1	7,57	28,6	0,23	3,03	55,4	53,6	1,55	761	0,87	1,23
Aland12	0,06	7,96	12	680	5,16	0,23	1,6	0,16	119,5	17,2	74	25,6	7,59	21,2	0,16	2,41	57,2	49	1,44	619	1,08	1,5
Aland13	0,07	7,83	5	730	2,87	0,38	1,45	0,3	107,5	13	78	26,4	5,09	23,1	0,15	2,94	50,4	43	1,08	370	0,26	1,25
Aland14	0,11	8,58	5,2	870	4,11	0,46	1,64	1,01	131	19,1	104	61,6	6,08	27,5	0,21	2,88	62,6	60,1	1,64	511	0,42	0,92
Aland15	0,09	7,85	3,1	750	2,69	0,37	1,47	0,3	121,5	12,9	80	32,2	4,81	24	0,21	3,25	58,6	45,1	1,08	339	0,3	1,25
Aland16	0,11	7,32	4,9	860	6,68	0,52	0,66	0,52	141	8,1	56	24	5,48	23,7	0,21	4,22	67,2	21,7	0,65	596	0,54	1,24
Aland17	0,07	6,99	4,1	710	3,69	0,28	0,77	0,25	71,7	23,1	77	18,6	4,32	23,2	0,16	3,1	31	34,4	0,93	1110	0,59	1,25
Aland18	0,08	7,43	9,8	1000	7,77	0,2	0,97	0,44	180	11,8	55	16,2	3,97	20,7	0,25	2,56	85,3	31,3	0,88	334	0,55	1,46
Aland19	0,12	7,7	7,6	820	34,3	0,3	1,98	1,02	138	17,3	84	41,9	4,59	27,5	0,23	2,59	66,5	61,8	1,38	668	0,59	1,01
Aland20	0,12	7,67	8,6	1090	2,99	2,37	3,49	1,92	156,5	14,9	70	36,6	4,45	21,9	0,43	2,8	90,8	25,7	0,96	1120	0,51	1,09
Aland21	0,09	5,57	5,3	630	2,52	0,53	1	0,5	84,5	18,1	85	58	4,45	22,9	0,22	2,48	50	59,4	1,17	724	0,41	0,96
Aland22	0,14	7,88	4,5	1470	2,65	0,3	1,52	1,34	162,5	22	97	69,3	5,53	23,6	0,36	2,81	103,5	50,7	3,39	1420	0,53	0,87
Aland23	0,09	9,01	10,9	800	3,5	0,5	0,96	0,3	122	21,2	103	28,3	6,22	29,6	0,2	3,1	56,9	60,1	1,92	1120	0,5	0,89
Aland24	0,08	7,81	6	640	2,21	0,6	0,65	0,13	73,4	16,5	86	23,8	5,05	25,9	0,18	3,11	34	59,4	1,39	527	0,51	1,1
Aland25	0,09	6,95	5,4	670	4,12	0,33	0,71	0,43	121,5	21,1	109	46,1	5,24	23,7	0,2	2,65	62,3	64,5	1,49	724	0,54	0,85

	Nb	Ni	P	Pb	Rb	S	Sb	Sc	Se	Sn	Sr	Ta	Te	Th	Ti	Tl	U	V	W	Y	Zn	Zr
	ppm	ppm	ppm	ppm	ppm	%	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	%	ppm	ppm	ppm	ppm	ppm	ppm	ppm
Aland1	21,4	26,5	1120	70,7	185,5	0,06	0,61	11,5	1	3,4	118	1,92	<0.05	28	0,361	1,12	4,7	77	1,6	15,2	284	151
Aland2	17,4	50,1	1790	35,6	165,5	0,01	0,38	17,1	1	3,3	141	1,45	0,07	20,2	0,483	0,93	8,6	118	1,6	27,1	172	140,5
Aland3	23,5	49,7	2910	55,8	234	0,02	0,39	19,1	2	4,2	90,1	2,57	<0.05	29,8	0,479	1,21	8,1	116	1,8	38,8	195	157,5
Aland4	16,9	40,2	2010	36,9	200	0,02	0,17	12,3	1	4,2	249	1,7	<0.05	14,4	0,349	1,08	5,6	82	1,1	27,2	144	109
Aland5	18,5	47,6	3040	34,9	145	0,02	0,41	21,6	1	3,5	190,5	1,62	0,07	17,9	0,453	0,76	7,9	108	1,3	38,3	150	171,5
Aland6	20,9	33,8	1900	50,6	253	0,01	0,26	13,1	2	4	85,2	1,64	0,05	24,5	0,364	1,64	9,2	85	1,7	27,8	160	111
Aland7	19,3	43,2	1880	40,4	177,5	0,02	0,26	15,7	2	3,4	118	1,99	<0.05	21,1	0,442	0,98	7,4	113	1,5	30,6	182	139,5
Aland8	16,9	29,7	1670	28,4	164	0,01	0,31	16,6	1	2,8	167	1,45	<0.05	15,3	0,552	0,91	4,9	98	1,1	28,7	173	139
Aland9	19,6	72,6	1250	41,3	171	0,04	1,35	20,2	1	3,3	124,5	1,63	0,08	22,1	0,533	1,21	7,2	154	1,3	22,8	185	120,5
Aland10	18,1	50,6	1640	38,4	170,5	0,03	0,26	16,5	1	3,7	130	1,38	0,1	24,4	0,492	1,26	8	136	1,4	29,7	153	91,1
Aland11	19,7	46,9	4180	32,1	184,5	0,03	0,34	19,7	2	3,7	136,5	1,28	0,05	21,1	0,488	1,18	5,4	124	1,5	26,9	182	117
Aland12	15,5	28,7	1340	33,6	138,5	0,04	0,46	16,8	1	3,1	176	1,49	<0.05	18	0,456	1,03	6,5	127	1,2	28,9	126	102
Aland13	16,1	35,4	6810	28,3	188,5	0,01	0,64	14,5	1	3,4	147,5	1,22	<0.05	19,3	0,395	1,15	3,5	89	1,1	21	156	106,5
Aland14	22,5	48,9	7910	27,3	201	0,02	0,69	20,2	1	3,7	198	2,29	0,05	20	0,487	1,1	3,8	111	1,6	26,5	283	129
Aland15	19,3	34,6	6280	27,5	193,5	0,01	0,67	14,6	2	3,5	172	2,02	<0.05	19,6	0,401	1,19	4,5	84	1,1	23,7	166	102
Aland16	14,2	25,8	9400	40	239	0,01	0,26	13	3	4,4	136	1,29	<0.05	15,9	0,316	1,39	6,4	66	1,2	36,1	87	84,8

contemporaneous with Typical and Late Comb Ware. Already by the Late Comb Ware tradition the craft changed and now materials rich in calcareous materials were added to the clay. Of the three analyzed sherds from Stockmyra, two had temper with solely calcareous material while the third also had a small element of quartz. This implies that tempering with quartz was still in use, though less frequently. The amount of calcareous material at this stage was very low, usually 10 to 12 %.

The Early Pitted Ware from Jettböle I was solely tempered with calcareous material, which shows how thoroughly this type of temper manifested itself on the Åland Islands. The younger Pitted Ware from Jettböle II however was more mixed either with quartz or calcareous material which again indicates a change in the craft.

The younger Pitted Ware from Glamilders (Jettböle II style) is relatively homogeneous with a high amount of temper rich in calcareous material (usually more than 20 %), while quartz has only been found in one sherd. Hence it can be determined that both the older and the younger Pitted Ware contains a large amount of calcareous material (Jettböle I and II styles respectively), but ceramics tempered with quartz also exists.

Kiukais Ware from Svinvallen and Myrsbacka represents a more varied craft, with sherds either tempered with quartz or some material rich in calcareous material. In the three analyzed sherds, the different types of temper were not mixed. It is noticeable that the amount of calcareous material temper in two of the sherds is very high and similar to the Pitted Ware sherds. Overall there are significant technological similarities between Pitted and Kiukais Ware.

Eight sherds from Jettböle Bergmanstorp and Alkärr that were included in the analysis were determined as mixed forms between Comb and Pitted Ware. This analysis has been aimed at studying if the qualities of the fabrics can indicate anything about their cultural origin (Tables 2 and 5). First it can be noted that one of the sherds, number 18 (ÅM476:372), from Alkärr is very different from the other analyzed sherds. This sherd has been manufactured from coarse clay without any temper. The sherd has been classified as Pitted Ware. Sherd number 14 (ÅM696:106) from Jettböle Bergmanstorp has been tempered with a relatively small amount of calcareous material and this sherd has a resemblance with Stockmyra samples, although the sherd from Jettböle Bergmanstorp also contained grog. The sherd has been interpreted as Late Comb Ware.

The other four sherds from Alkärr and Jettböle Bergmanstorp are similar to the Early Comb Ware from Vargstensslätten. It is the element of temper solely containing quartz that places the sherds in this group. Sherd number 16 from Alkärr (ÅM476:412) most resembles the material from Vargstensslätten. The fabric in this sherd contained large grains of temper and it has been determined as possible Comb Ware. The other three sherds have similarities with Vargstensslätten, but they have a slightly finer temper. There was one sherd from Jettböle Bergmanstorp (ÅM696:84) tempered with both calcareous material and quartz, which can be seen as evidence for changing pottery craft tradition. The ceramics that represent mixed or transitional forms have been confirmed to have significant similarities with the Uskela Ware (see Vikkula 1981) within the Late Comb Ware tradition. The relationship in typology and craftsmanship between Uskela Ware in the

Table 4. Compilation of the thin section analysis.

Pottery	Site	Temper	Notes
Comb ceramics, early	Vargstensslätten	Quartz	Large grains, > 3.0 mm. High amount of temper.
Comb ceramics, late	Stockmyra	Calcium, (quartz)	Mainly lime/calcium temper. Low amount of temper. Small grains.
Comb ceramics, Pitted ware. Transition	Alkärr. Jettböle, Bergmanstorp	Quartz. Calcium. Natural	Either quarts or lime/calcium. Temper not mixed. Varying.
Pitted ware ceramics	Glamilders, Jettböle II, Jettböle II	Calcium, quartz	Mainly lime/calcium temper. High amount of temper.
Kiukais ceramics	Svinvallen. Myrsbacka	Calcium, quartz	Either quarts or lime/calcium. Temper not mixed. Varying.

Table 5. Mixed form sherds and their resemblance to specific ceramic groups.

Site	ÅM	Pottery	Temper	Resembles to	Notes
Jettböle, Bergmanstorp	696:80	Comb ceramics, Pitted ware. Transition	Quartz	Vargstensslätten, early Comb ceramics	Slightly finer than Vargstensslätten
Jettböle, Bergmanstorp	696:106	Comb ceramics, Pitted ware. Transition	Calcium (grog)	Stockmyra, late Comb ceramics	-
Jettböle, Bergmanstorp	696:108	Comb ceramics, Pitted ware. Transition	Quartz	Vargstensslätten, early Comb ceramics	Slightly finer than Vargstensslätten
Jettböle, Bergmanstorp	696:59:00	Comb ceramics, Pitted ware. Transition	Quartz	Vargstensslätten, early Comb ceramics	
Jettböle, Bergmanstorp	696:84	Comb ceramics, Pitted ware. Transition	Quartz, calcium	Stockmyra, Glamilders	
Alkärr	476:412	Comb ceramics?	Quartz	Vargstensslätten, early Comb ceramics	Same as Vargstensslätten
Alkärr	476:505	Comb ceramics, Pitted ware. Transition	Quartz	Vargstensslätten, early Comb ceramics	Slightly finer than Vargstensslätten
Alkärr	476:372	Pitted ware ceramics?	Natural	-	Own group

Finnish mainland and the Åland Islands needs to be further investigated. It is obvious that the ceramic material on the Åland Islands displays a wide range of variation during the Neolithic.

Comparison with Neolithic ceramics from mid-eastern Sweden

On the Swedish mainland and in the region of Uppsala the Neolithic ceramics was mainly manufactured from fine clays tempered with crushed granitic rock (Brorsson et al. 2007). Materials rich in calcareous material were also used while grog is attributed to the Battle Axe culture (Larsson 2009: chapter 7 and 8). Within the analyzed Corded Ware material from Sweden, clay rich in calcareous material occur, but Corded Ware/Battle Axe Ware from the Åland Islands have not been analyzed and ceramics of this type only occurs as single sherds on Pitted Ware settlements on the Åland Islands (Stenbäck 2003: 82). However, grog was found in one of the sherds from Jettböle Bergmanstorp and its significance may also be symbolic, where the grog from an old pot was used as temper into a new one so that the the old pot was brought back into use again. Naturally tempered clays were also used within the Pitted Ware culture. At the Högmossen site in northern Uppland three out of 23 analyzed sherds was ascribed to this group of ware (Brorsson et al. 2007: 420). It is worth noting that of around 100 analyzed Pitted Ware sherds from Mälardalen fewer than five were manufactured from coarse clays without adding extra temper. This analysis indicates that Pitted Ware on the Åland Islands was manufactured from the same type of raw material as the contemporary ceramics from Mälardalen.

The transition from Comb Ware to Pitted Ware on the Åland Islands took place around 3300 BC, i. e. at the transition between the Early and Middle Neolithic according to the Swedish periodization. It is about this time Pitted Ware on the Swedish mainland changed from Fagervik I and II into the Fagervik III phase (Larsson 2009: 224). Fagervik I is considered synonymous with the mid-Swedish Funnel Beaker culture. Analysis made on Funnel Beaker pottery from the site Bålmyren in Uppland Påljungshage and Östra Vrå in Södermanland have shown that the ceramics was mainly manufactured from fine clays tempered with crushed granitic rock with relatively large grains (Brorsson 2005; Brorsson et al. 2007: 420; Brorsson 2008a). Another important result was that the temper in several of these wares was sieved prior to adding it to the clay. Analyses of Funnel Beaker pottery have also been performed on sherds from the sites of Nävertorp and Mogetorp, along with additional sherds from Östra Vrå in Södermanland (Brorsson 2008b). The results indicate significantly larger variation in the pottery craft, where several different types of clays and both sieved and unsieved temper occurred. Despite this, it is possible to determine that the Funnel Beaker pottery in Mälardalen and Uppland was principally manufactured from sorted fine clays and tempered with relatively large grains of granite that had been sieved. The Funnel Beaker pottery is younger, but technologically it is the same type of craftsmanship as in the Early Comb Ware from Vargstensslätten. In the assemblage from the site Nävertorp in Södermanland there were a few sherds with a possible connection to the Pitted Ware culture (Brorsson 2008b).The analysis showed that these two sherds had been tempered with bone or some other material rich in calcium as well as with crushed granite, and perhaps this is one of the earliest traces of limestone temper and the emerging Pitted Ware culture. The settlement at Nävertorp has been dated to 3800–3400 BC and it is possible that the temper rich in calcareous material appeared in the latter part of this period in Södermanland. On The Åland Islands this temper appeared at the transition between Early and Late Comb Ware. The phenomenon to temper the ceramics with material rich in calcareous material may thus be older on the Åland Islands than on the Swedish mainland.

Kiukais Ware is found on the Åland Islands in the Late Neolithic (Meinander 1984; Stenbäck 2003: 83) and it is partly contemporary with the Swedish Late Neolithic pottery. There are only a few analyses made of Late Neolithic pottery from the area around lake Mälaren, one is from the Norslunda site close to Arlanda in Sigtuna, Uppland (Brorsson 2009). Four sherds from Norslunda were analyzed and all of them had been manufactured from sorted fine clays tempered with crushed granitic rock and the fabric did not contain any material rich in calcareous material. Pitted Ware sherds from the same site were also studied and several of them did contain calcareous material, which indicate a variable craft between the Pitted Ware and the Late Neolithic pottery. From the Åland Islands, Kiukais Ware from the sites Svinvallen and Myrsbacka have been analyzed and two out of the three sherds are very similar to the Late Neolithic pottery from Norslunda and indicate similarities in the pottery craft.

It can be determined that the Åland Islands and Mälardalen experienced the same change in the pottery craft from the Early to Late Neolithic. It is possible that the temper rich in calcareous material occurred a little earlier on the Åland Islands, but the analysis cannot confirm which region was first to abandon it. One of three sherds of the Late Neolithic Kiukais Ware on the Åland Islands has temper rich in calcareous material while none of the four analyzed Late Neolithic sherds from Norslunda contained calcareous material. This very vague basis may indicate that temper rich in calcareous material continued to be used a bit longer on the Åland Islands than on the Swedish mainland, but more of Late Neolithic materials from the Sweden needs to be analyzed to confirm this hypothesis.

Conclusion

The thin section analysis of Early and Late Comb Ware, Pitted Ware and Kiukais Ware from the Åland Islands indicates continuity in the pottery craft and in the choice of clay during the entire Neolithic period, and it also indicates a technological similarity with pottery traditions on the Swedish mainland. The change in pottery style has been demonstrated earlier in the classification of the ceramics into traditional typologies. This study shows that it is possible to see differences also in the choice and handling of the temper in the ceramics. The change in preference of temper added to the vessels does not however occur at the same time as the typological shift between pottery traditions. The Early Comb Ware vessels have a temper of rock and quartz which already in the Late Comb Ware parallels with the introduced limestone tempering. This introduction is earlier than what is confirmed on the Swedish mainland. Temper rich in calcareous material then occur in Pitted Ware on the Åland Islands, while in the Late Neolithic Kiukais Ware either one or the other is chosen but the materials are never mixed. The introduction of the temper rich in calcareous material that manifests itself in the Pitted Ware craft at Jettböle I–II and Glamilders are probably not introduced to the islands as a Pitted Ware innovation but arrived from the east.

The Early Comb Ware sherds that have a black outside and a fine polished/smoothed surface do not differ from the rest of the sherds analyzed. The treatment of the surface has raised questions why the surface almost looks like "asphalt", but the analysis shows that this pottery is no different from the rest of the Early Comb Ware on the Åland Islands.

Provenance analysis (ICP-MA/ES) confirms that a local pottery craft most likely existed during the whole Neolithic period on the Åland Islands. This is also valid for the earliest Comb Ware, which doesn´t display a different craft or a clay material with differing provenance as earlier research has suggested. This study neither confirms nor dismisses the occurrence of Ancylus clay in the material. The aberrant ceramics that most likely is not manufactured on the Åland Islands is a fragment of an idol and a Pitted Ware sherd from Glamilders, while the rest of the analyzed Pitted Ware material is locally manufactured.

The communication and movements throughout the Baltic Sea are visible in the material culture on the Åland Islands. Pots, clay idols and other types of artefacts with a provenance outside the Åland Islands are clear indications of existing contacts in different directions. The development of the ceramic technology and the fact that we can see influences from different traditions in unique vessels on the Åland Islands illustrate the spread of innovations and ideas in the Baltic region. The thin section analysis showed that a sherd from Alkärr determined as originating from an older Pitted Ware vessel had a divergent ware and if anything has a resemblance to ceramics from the Pitted Ware site Högmossen in Uppland. However, the result of the ICP analysis indicated that the sherd from Alkärr nevertheless probably has its provenance on the Åland Islands.

In this analysis, it has been suggested that the ceramics believed to represent mixed forms of Comb Ware and Pitted Ware display a reinforcement of the past and the earlier pottery traditions. At the site Jettböle Bergmanstorp grog from an older vessel has been mixed into the fabric of a new vessel. From this site and from the site Alkärr, vessels of Comb Ware resembling Uskela Ware have been found, made with temper and clay similar to the earliest Comb Ware found at Vargstensslätten. It is possible that we see traditional features being emphasized in the transition into new techniques.

The aim of this study is to contextualize the pottery traditions on the Åland Islands in a larger perspective. The study has shown that pottery was locally manufactured on the Åland Islands during the entire Neolithic period. The difficulties in classifying some of the ceramics into existing typologies and the local technological choices visible in the ceramics demonstrate this. Comparative studies of ceramic materials from the Swedish mainland confirm contacts to the western shores of the Baltic sea, and there is evidence of a common ceramic technology during the period irrespective of typological traditions. To fully understand the communication and contacts in the Baltic Sea area and the relationship between the pottery traditions, further studies are necessary. Pottery from Neolithic sites in mainland Finland will be analyzed in order to broaden the perspective and make comparisons possible. The Kiukais Ware and the Late Comb Ware traditions on the Åland Islands have proven difficult to contextualize, and they have an important role in future discussions on ceramic technologies, typologies and as an intermediary to the understanding of the Neolithic in the Baltic Sea region.

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The reconstruction of functional zones at Neolithic to Early Iron Age sites in the Neva river basin (Russia) by means of geochemical markers

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Abstract

Anthropogenic activity by ancient people influences the chemical composition of soils, enriching or exhausting certain chemical elements. The application of geochemical methods allows us to obtain important information for interpreting functional zones at settlements (for example, places of habitation, cooking zones, fireplaces, and so on). Such research was conducted at two sites dating from the Neolithic to the Early Iron Age in the Prinevsky region – Okhta 1 and Podolije 1. Complexes of geochemical indicators connected with certain functional zones of anthropogenic activity were identified. The burial place at the Okhta 1 site is marked by abnormal values of the bioindicators P_2O_{5antr} and CaO_{antr}. The geochemical complex at the Podolije 1 site, including indicator ratios of K_2O_{antr}, Rb_{antr}, CaO_{antr}, and Sr_{antr}, can characterize fireplaces (K_2O_{antr} and Rb_{antr} make up a part of ashes) and zones of fish and animal preparation (CaO_{antr} and Sr_{antr} are elements of bone tissues). Such investigations have been conducted at only a few archaeological sites in the territory of Russia, and this research is unique.

Keywords: geochemical anthropogenic indicators, environmental reconstruction, archaeology, Okhta 1 site, Podolije 1 site, Lake Ladoga, Stone Age

Introduction

At present, different scientific methods are used at archaeological excavations to obtain more information about the palaeoenvironment, the period of habitation, and other features of ancient human life. One important task is the reconstruction of functional zones at ancient settlements. Sediments and soils affected by anthropogenic activity reflect this information in their physical and chemical characteristics. Valuable information about anthropogenic activity at settlements can be obtained from the geochemistry of soils and cultural deposits. The activities of prehistoric people influenced the variations in the chemical compositions of the soil by enriching it with or depleting it of certain chemical elements, ultimately creating that which constitutes archaeological soils and cultural layers (Oonk et al. 2009). High concentrations of heavy metals in the soils of archaeological sites correlate closely with the anthropogenic activity of ancient people (Aston et al. 1998; Entwistle et al. 1998; Wilson et al. 2008). This can be explained by the fact that the geochemical markers of anthropogenic activity are conserved in the deposits for many years.

The most frequently used chemical elements for the determination of anthropogenic activity at ancient sites are P, Ca, K, Na, and Mg, and the microelements used include Cd, Cr, Cu, Pb, and Zn (Lutz 1951; Aston et al. 1998; Schlezinger & Howes 2000; Terry et al. 2004; Cabala et al. 2012). If the archaeological sites are located in areas with complex relief, the primary distribution of chemical elements may have changed as a result of erosion after the elements were originally deposited in the soil. Soil erosion processes connected with the effects of water, wind action, and ploughing redeposit the geochemical components downhill. The destroyed material accumulates in depressions and at the feet of slopes as colluvium. Research at this kind of archaeological sites with complex relief was described by Oonk et al. (2009). These cases require the development of a uniform methodological approach, the determination of a precise geochemical background, and the understanding of geochemical processes at the site. Nevertheless, even in complex geomorphological contexts, anthropogenic geochemical indicators can be used to reconstruct functional zones at ancient settlements.

Aston et al. (1998) considered the connection between high concentrations of heavy metals in soils and ancient anthropogenic activity. High concentrations of heavy metals can be connected with different types of ancient anthropogenic activity as a result of which chemical elements of anthropogenic origin have accumulated in soils. For example, these elements may indicate the development of ancient settlements, animal breeding in close quarters, the use of fire (fireplaces, slash-and-burn cultivation), ancient metallurgy, or subsistence activities (production of leather, processing of agricultural crops). As Schlezinger & Howes (2000) suggest, increased phosphorus concentration in soils can be connected with the physiological activity of humans and animals in their habitation areas, the decomposition of animal and plant organisms in settlement areas, and the use of animal dung as fertilizer. Several researchers (Terry et al. 2000) suggest that phosphorus can accumulate in the soils of ancient settlements as a result of food preparation and the utilization of waste products. The different phosphorus compounds in soils are stable to oxidation, reduction, leaching, and dissolution (Lima da Costa & Kern 1999; Wells 2004). According to several scholars (Proudfoot 1976; Stevenson 1986), newly mineralized inorganic phosphorus, while generally retained in the soil, is subject to some vertical translocation in the soil due to factors directly affecting adsorption, such as pH, cation exchange capacity, and cation availability. The distribution of inorganic phosphate is therefore determined by the chemistry and adsorption kinetics of the soil throughout the period of decomposition and precipitation (Schlezinger & Howes 2000). Phosphorus is the main component of human and animal bones, a component of living tissues (in the form of nucleic acids, phospholipids, nucleotides, and so on), and a component of everyday products (such as wood, plant, or meat products) (Sanchez 2007). The phosphorus concentration in the soil increases depending on the supply of different organic materials, such as plants and animals, that are used by people. The phosphorus content in cultural layers is an indicator of the intensity of human occupation in the area. The concentration of organic materials containing phosphorus, accumulated in the process of human activity, is proportional to the time of human occupation and the growth of the population (Marwick 2005).

High concentrations of potassium (K) and sodium (Na) can be connected with the presence of fire ash in the areas of fireplaces (Middleton & Price 1996). In soils, potassium (K), sodium (Na), and rubidium (Rb) are the main components of feldspar and plagioclase minerals. Rubidium (Rb) could be taken up by plants as a substitute for potassium (K), which it chemically resembles. In this case, rubidium behaves like potassium. We can also use rubidium as an ash indicator for some types of deposits. We can therefore consider these elements as anthropogenic components if we have any other evidence for human activity at the archaeological site, such as anomalous concentrations in comparison with the background or a correlation between high concentrations and any remains of charcoal or fire ashes.

Increased concentrations of iron (Fe) and mercury (Hg) at settlements can be explained by the use of different natural pigments in rituals. The combination of elements such as Fe, Mn, Zn, and Cu can indicate areas of waste disposal, burials, cesspools, or rubbish after feasts (Wells et al. 2000). The chemical composition of soils in settlement areas can therefore provide information about different features of functional zones at settlements. According to most researchers, soils have the ability to withhold and absorb chemical elements resulting from anthropogenic activity during many years. At archaeological sites, these materials usually consist of household waste, bones, metal slag, ashes, dung, and the remains of burials and cremations. Investigations in the past few years (Wilson et al. 2005) showed that using just one chemical element or its compound to determine features of archaeological objects or functional zones at settlements is not always correct because the results obtained could be explained by several archaeological and natural contexts. The accumulation of different chemical components depends on the different natural factors of sedimentation and the further diagenetic transformations of sediments, the duration and intensity of human occupation at the site, and other factors. The method of “multi-element” analysis (Lima da Costa & Kern 1999; Parnell & Terry 2002; Wilson et al. 2005), which has been applied relatively recently, allows us to establish a complex of several chemical components and to consider their connection with different functional zones.

The first results in the development and application of phosphate analysis in the territory of the USSR were obtained in the 1950s. This method was applied to search for ancient settlements in Estonia and Latvia (Velleste, 1952; Shtobe 1959). In the beginning of the 1960s, phosphate analysis was used to search for Neolithic and Bronze Age sites in north-western Russia (Miklyaev & Gerasimova 1968). At present, phosphate analysis is extensively used to examine and search for archaeological sites in the territory of Russia (Anderson et al. 2009). In contrast, the multi-element approach is not commonly applied in Russian archaeology. Only a few sites were investigated with this method (Kulkova et al. 2012). These investigations are therefore very important for Russian archaeology and the further development of this approach is significant. At present, the method used in Russia consists of sampling a square of the site and applying multi-element analysis with data processing by mathematical statistics in order to reconstruct functional zones at archaeological sites (Kulkova 2012). The application of statistical analysis methods allows dividing the complex of chemical elements analyzed in anthropogenic soils into several groups.

The associations of chemical components in groups with close correlation bonds testify that these elements were formed in the same geochemical environments. We can determine the groups of chemical elements that are connected with different types of anthropogenic activity. Together with the method of multi-element analysis, the indicator ratios of chemical elements can be applied to the reconstruction of functional zones. These indicator ratios of chemical elements reflect the degree of enrichment of anthropogenic elements in comparison to their background concentrations in the soils of the settlement and outside of it (Oonk 2009). The geochemical methods can be used at multilayer sites to analyze cultural layers in cases where the living and household structures have been destroyed. This method provides additional information for interpreting different areas of the site, such as pits, the remains of constructions, or zones around fireplaces. The geochemical analysis of soils and deposits was carried out at two archaeological sites located in the Neva river basin in order to reconstruct their functional zones.

The archaeological sites under study in the Neva river basin

The most thoroughly studied archaeological sites at which the interdisciplinary investigations have been carried out are Okhta 1 and Podolije 1 (Figure 1) (Gusentsova & Sorokin 2011; Kulkova et al. 2014; Gusentsova et al. 2014). It should be noted that the main period of their occupation was at the same time during the Late Neolithic and Early Bronze Age. The method of geochemical investigations was applied to the study of cultural layers connected with a date of approximately 3300 cal BC (Gusentsova et al. 2014).

The Neolithic-Early Iron Age site of Okhta 1

The Okhta 1 site is located in the center of St Petersburg near the confluence of the Neva and Okhta Rivers. The cultural remains of the ancient site were excavated in an area larger than 10,000 m^2. Excavations in the central and

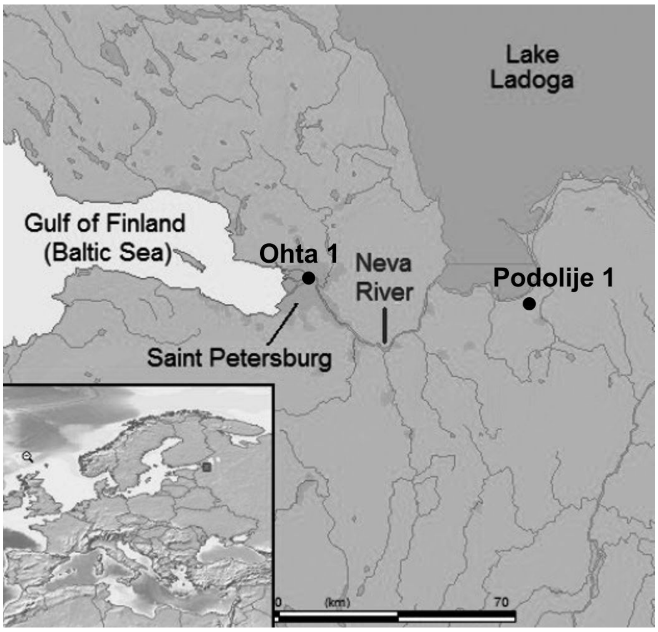

Figure 1. Locations of the Okhta 1 and Podolije 1 sites.

southern parts of the study area encompassed about 6,700 m^2 (excavations in 2008–2009). The cultural layers of the prehistoric settlements are situated under alluvial sandy sediments with a thickness of 1–1.5 m, lying under the buried soil of the Middle Ages. So far, this is the only site dating to the Neolithic–Early Iron Age known from St Petersburg. The collection of archaeological finds totals about 1,200 objects, including pottery, stone tools, wooden carvings, and amber jewellery. The remains of wood constructions were discovered for the first time in the St Petersburg region. These artefacts are mostly wood piles, strips, and rails. Due to the number of archaeological finds and the preservation of organic finds, the Okhta 1 site is a unique and rare object of cultural heritage in the territory of the Baltic Sea and Northern Europe. The results of interdisciplinary investigations provided us with a significant database for reconstructing the palaeogeographical conditions, the processes of cultural layer formation, and the development of cultural-historical stages in the region. These results have been published elsewhere (Sorokin et al. 2009; Kulkova et al. 2012; Gusentsova & Sorokin 2011, Kulkova et al. 2014a, Kulkova et al. 2014b).

Neolithic-Early Bronze Age site of Podolije 1

The Podolije 1 site is located on the southern shore of Lake Ladoga at an absolute height of 11.8–12.1 m. During the period of settlement, the site was situated in the coastal zone of Lake Ladoga. When the Lake Ladoga transgression occurred, the site was flooded and people abandoned it. Two different cultural layers can be identified at this site. The upper cultural layer consists of yellow-grey sand with a thickness of 0.2–0.8 m. The lower cultural horizon consists of peat interlaid with yellow sand (the thickness of the cultural layer is 0.8 –1.5 m). The peat was formed in conditions of shallow water in a swamped basin. Archaeological finds are represented by an assemblage of different types of pottery, a collection of stone and bone tools for hunting and fishing, amber adornments, and wooden remains of fishing constructions. According to the radiocarbon date, the site dates from the 5th to the 3rd millennium BC (Gusentsova et al. 2014).

Materials and methods

At the site of Ohkta 1, the deposits were sampled from a square of the cultural horizon consisting of yellow sand located on a grid of 7.8 x 6 m in excavation № 7/2-1 (Figure 2). The soil samples were taken at intervals of 0.6 m on the coordinate grid. The coordinates of the primary point of sampling were registered by GPS. The 154 samples were sampled and analyzed. According to the archaeological finds, this zone can be interpreted as a burial place. Finds from this location include a human tooth, several amber adornments, traces of red ochre, and a

Figure 2. The sampling location in excavation № 7/2-1 of the Okhta 1 site.

stone construction. Not very many archaeological finds were found inside the burial area. There are several spots of red-brown sandy loam including charcoal particles and several small fragments of ferruginous bones. The human tooth was found among the bones. In the northern part of one of the red spots, there was a circle built of several big boulders. The necklace, which was made of 13 amber oval pendants resembling buttons with V-holes, was found close to the red spot. Two other pendants were found close to other red spots. The oval stone construction can be seen on the excavation plan (Figure 2). The geochemical method was applied to check this location.

Sampling at the Podolije 1 site was conducted on a square of excavation 2 (sq. 4–11/X–Ш) on the surface of the yellow-grey sand at intervals of 0.5 m on the coordinate grid (Figure 3). Altogether 76 samples were analyzed from this area. In this part of the excavation, the narrow terrace of an ancient channel had been revealed on the basis of geomorphological data. In the shore zone of this channel, earth structures with fragments of pottery, stone tools, animal bones, and charcoal were found. The three background samples were taken from the same layers outside of cultural horizons.

The chemical composition of the deposits from the Okhta 1 and Podolije 1 sites was determined by XRF analysis by means of the vacuum wavelength dispersive X-ray fluorescent WD-XRF scanning spectrometer "Spectroscan Макс-GV" in the Lab of Geochemistry of the Environment of Herzen State University. This is a desktop WD-XRF spectrometer controlled by an external computer. The measuring system of the spectrometer is in the vacuum chamber, while the samples are at

Figure 3. The sampling location in the excavation of the Podolije 1 site.

the ambient pressure, so no He is required for the sample chamber and all samples (including liquid and powder) may be studied with no special measures taken. Previously, the deposit samples were dried in an oven for 24 hours at a temperature of 105 °C. After this procedure, the removal of large particles (generally particles greater than 2 mm in diameter), and sample homogenization to powder in an agate mortar, about 1 gram of powdered sample was fired in an oven for the burning of organics at a temperature of about 550 °C for 40 minutes. The samples were pressed in tablets used for measurement in the XRF spectroscan.

The Surfer Mapping Software (Version 8.0) was applied to map the distribution of geochemical indicators of anthropogenic activity in the studied area.

The results of the geochemical investigations

The Okhta 1 site

Based on the geochemical analysis, there are anomalies in the concentrations of several chemical elements connected with anthropogenic activity in the cultural deposits from the sample of excavation № 7/2–1 at the site of Okhta 1 in comparison with their background concentrations (Nesterov et al. 2011, Kulkova et al. 2014b). The distribution maps of phosphorus P_2O_5(%), anthropogenic calcium $CaO_{antr} = CaO/(CaO+Na_2O)$ (%), and iron Fe_2O_3(%) in deposits in the sampled square of cultural layer are presented in Figures 4 and 5. The indicator CaO_{antr} was calculated as the ratio between CaO_{tot} and the sum of CaO_{tot} and Na_2O. In this case, we separated anthropogenic calcium from lithogenic calcium, which is found in the mineral composition of deposits. The concentrations of other anthropogenic elements in the deposits of this site are on the background level. These elements (MnO, K_2O, and Rb) were therefore not used for reconstructions (Figure 6).

The Podolije 1 site

At the Podolije 1 site, there are important indicators that help to understand the features of the ancient terrace microrelief. The map of artefact distributions is presented in Figure 7. The variations in the concentrations of the main chemical components of sand deposits, such as aluminium (Al_2O_3,%) and silica (SiO_2,%), were used for this purpose. The distribution maps of these components reflect the changes in the ancient microrelief at the excavation site (Figures 8 and 9). The high concentration of phosphorus (P_2O_5, %) (Figure 10) is registered in the big depression in the ancient channel. In the deposits of this depression, high concentrations of manganese (Mn), barium (Ba), and iron (Fe) were registered (Figure 11). In order to separate the component fraction of anthropogenic origin from the lithogenic fraction, the ratio of concentrations of total chemical elements in the deposits was used. The anthropogenic calcium CaO_{antr}(%) was calculated as CaO_{antr}= $CaO/(CaO+Na_2O)$(%) and its distribution is shown in Figure 12. In the case of these sites, sodium (Na_2O) has a totally lithogenic character. The map of anomalies in anthropogenic strontium (Sr_{antr}) = $Sr/(Sr+Na_2O)$(%) is presented in Figure 13. Calcium is replaced by strontium in the carbonate apatite of bones. The distribution of concentrations of K_2O_{antr}=$K_2O/K_2O+Na_2O)$(%) and Rb_{antr}=$Rb/(Rb+Na_2O)$(%) are shown in Figures 14 and 15. In the sediments of this site, potassium and rubidium have a strong correlation with each other and are connected with the ash component of this site.

Discussion

At the Okhta 1 site, the geochemical anthropogenic indicators connected with the accumulation of bones and tissues (phosphorus P_2O_5 (%) and calcium $CaO/(CaO+Na_2O)$(%)) have anomalies in the area where a human tooth was found. In this location, an anomaly in the concentration of iron (Fe_2O_3 (%)) is registered as well. The highest iron concentrations are connected with the areas of red spots. The mineral composition of these sediments consists of ochre minerals. Anomalies in the iron concentration could therefore indicate ritual activity in this place. In areas where there were anomalies in the combination of these elements, different archaeological artefacts, such as the tooth, amber adornments, ochre, and a stone construction were found. The locations of these finds are connected with the inside area of the contours of the main element indicators. All this evidence gives reason to believe that this place was used for burial in the 4th millennium BC.

The geochemical mapping of the whole excavation square revealed that the areas of anthropogenic indicators have maximums in the area connected with burial. The character of geochemical indicator distributions and the character of sedimentation (Kulkova et al. 2014b) reveal that the burial had taken place in the shore zone of the shallow Littorina Sea and that it was partly rewashed during the transgressive stage of the basin. The geochemical data on anthropogenic activity indicate maximum concentrations in the zone with artefacts, whereas the concentrations in deposits of other parts of the excavation are extremely low. The relatively high concentrations of anthropogenic elements in comparison to the background concentrations, as well as the presence of burial artefacts, serve as evidence

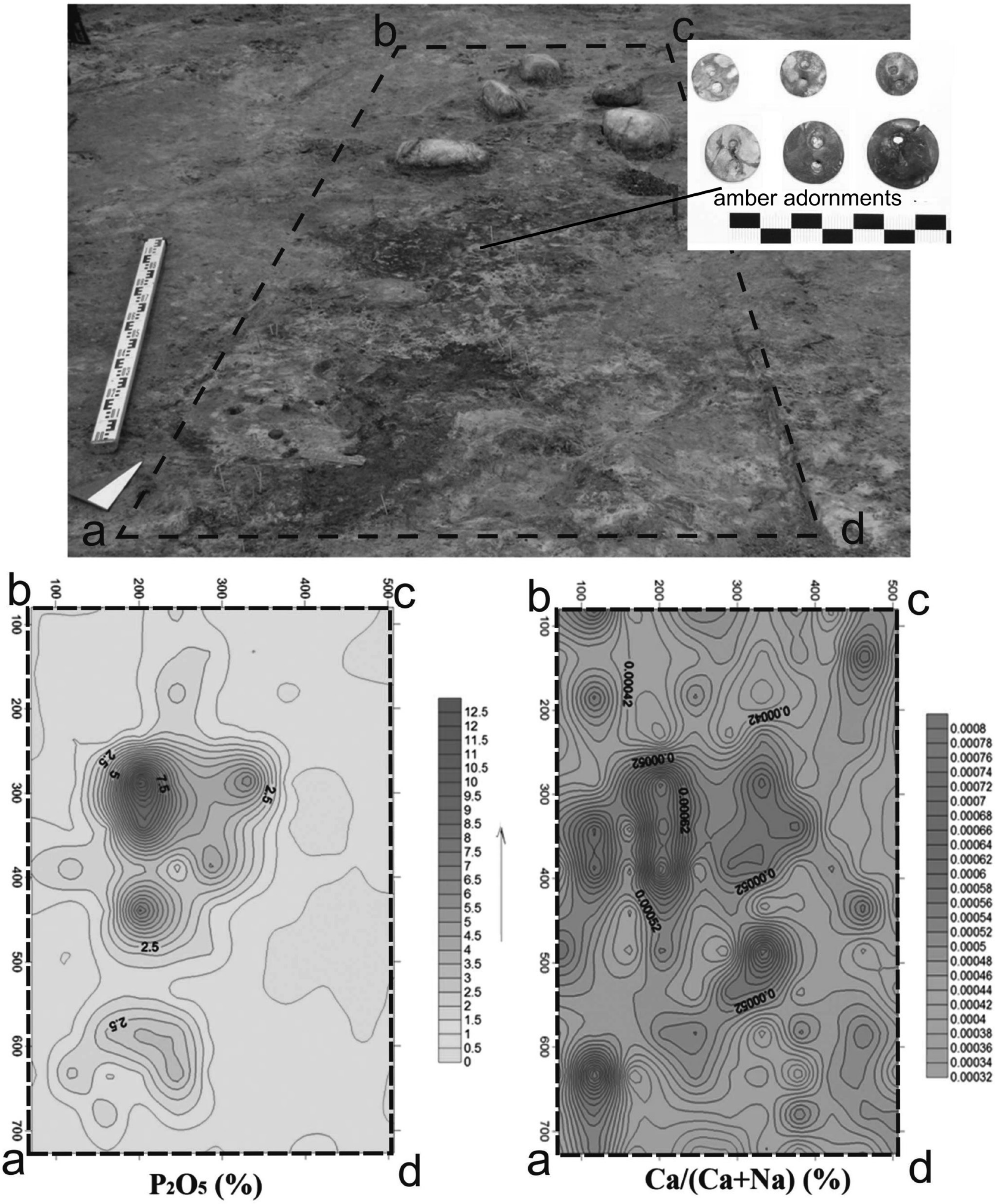

Figure 4. The distribution of phosphorus (%) and anthropogenic calcium (%) in the deposits of excavation 7/2 (Okhta 1 site).

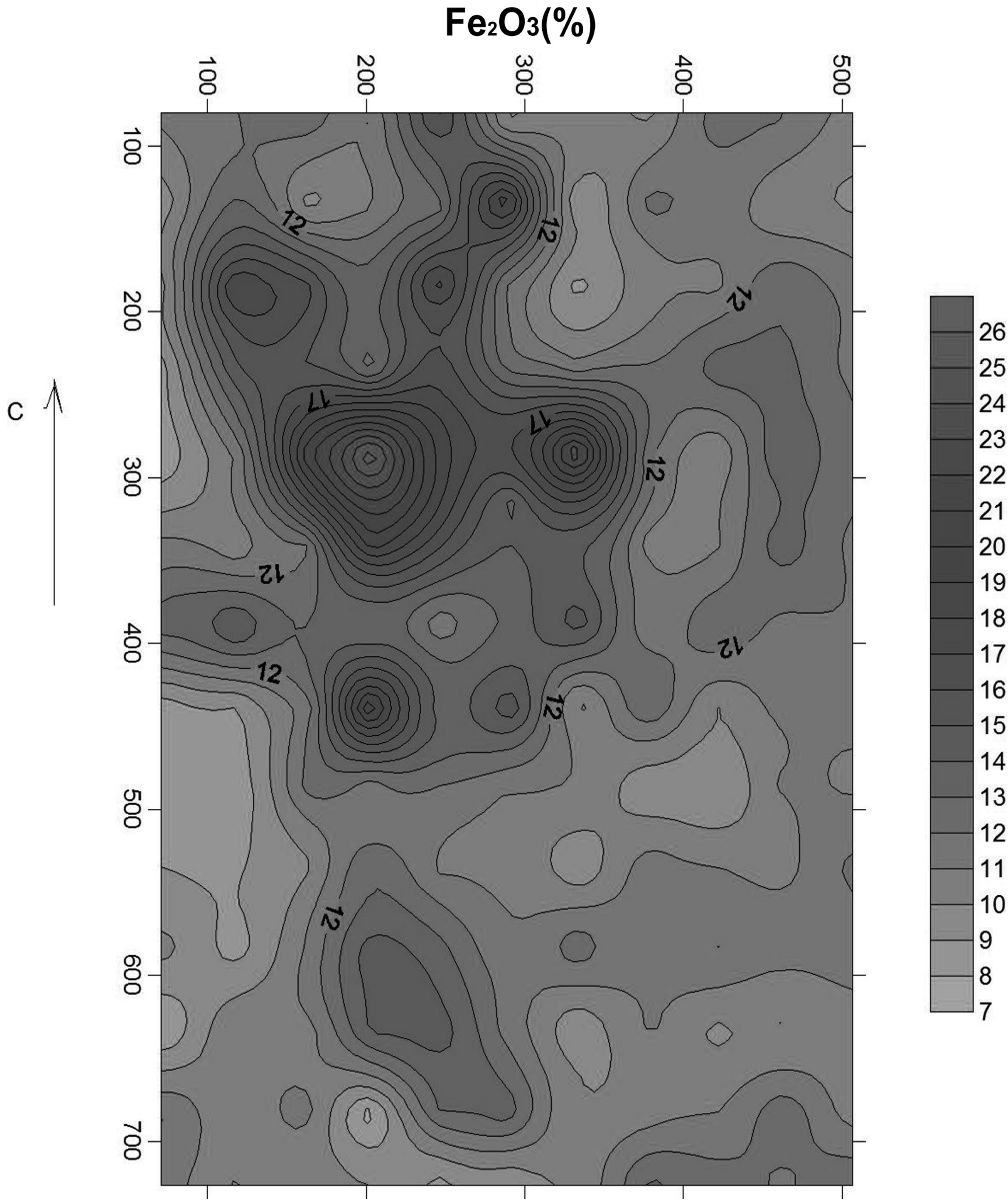

Figure 5. The distribution of iron (%) in the deposits of excavation 7/2 (Okhta 1 site).

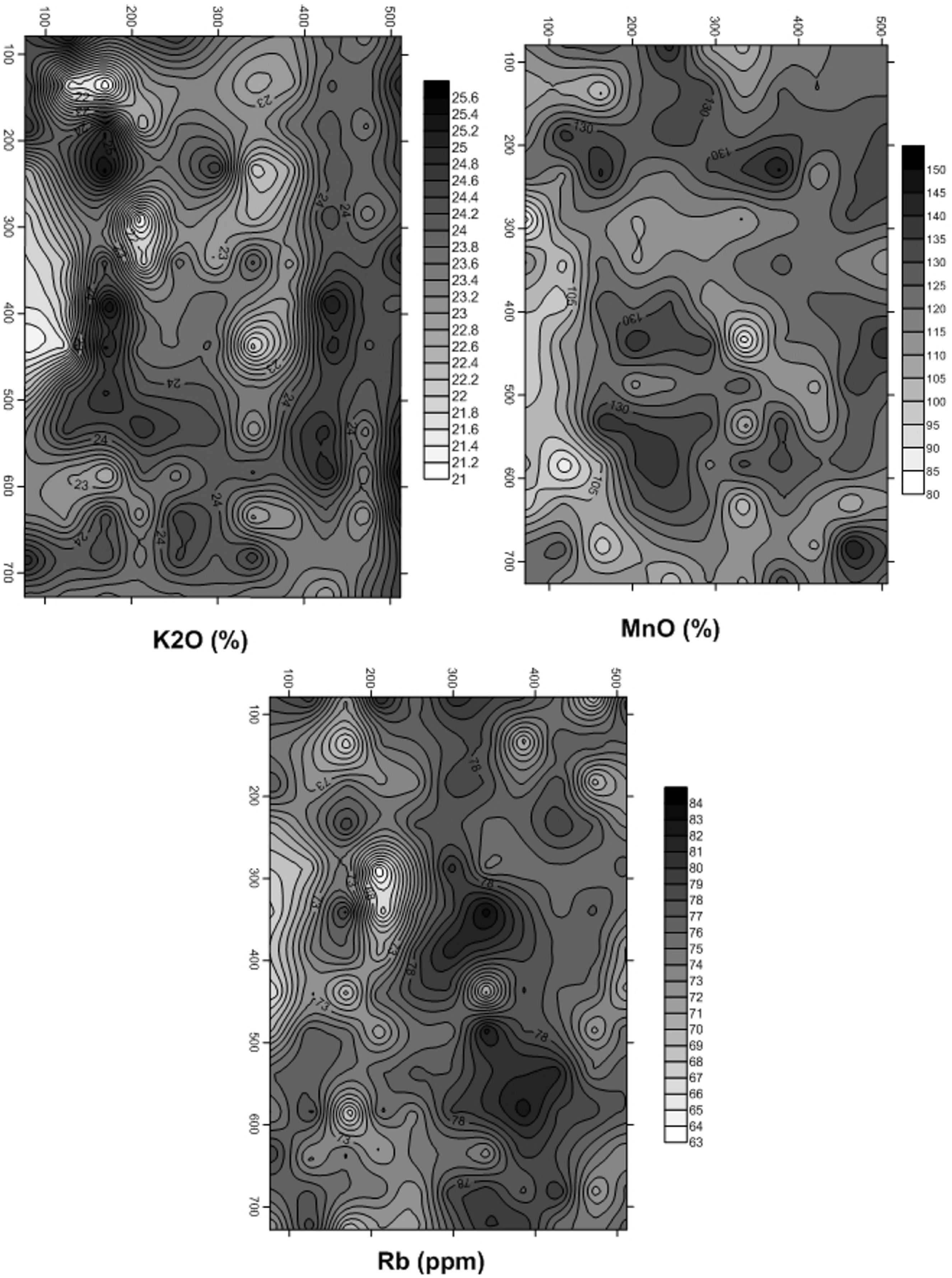

Figure 6. The distribution of potassium (%), manganese (%), and rubidium (ppm) in the deposits of excavation 7/2 (Okhta 1 site).

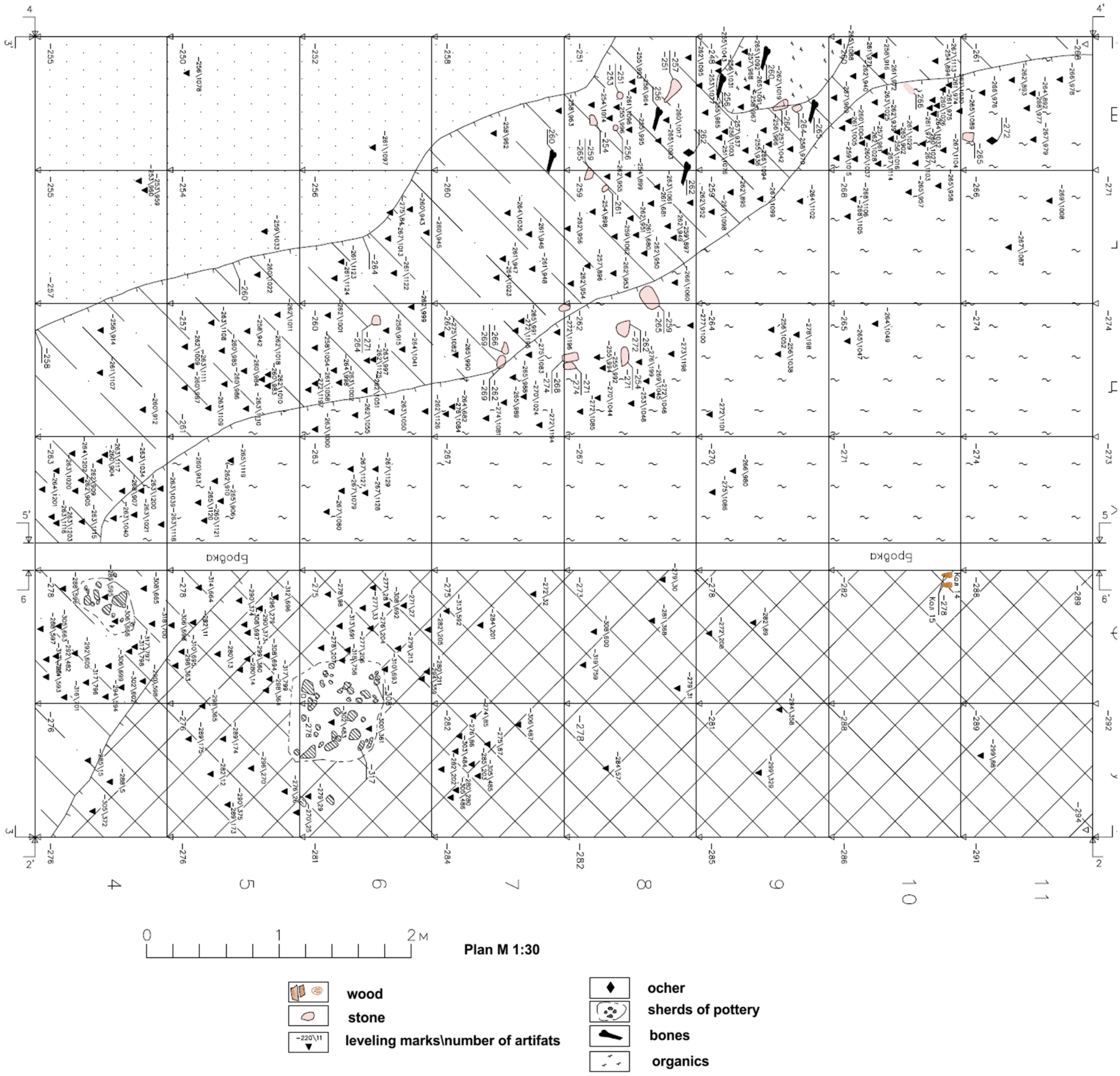

Figure 7. Artefact distribution of the Podolije 1 site.

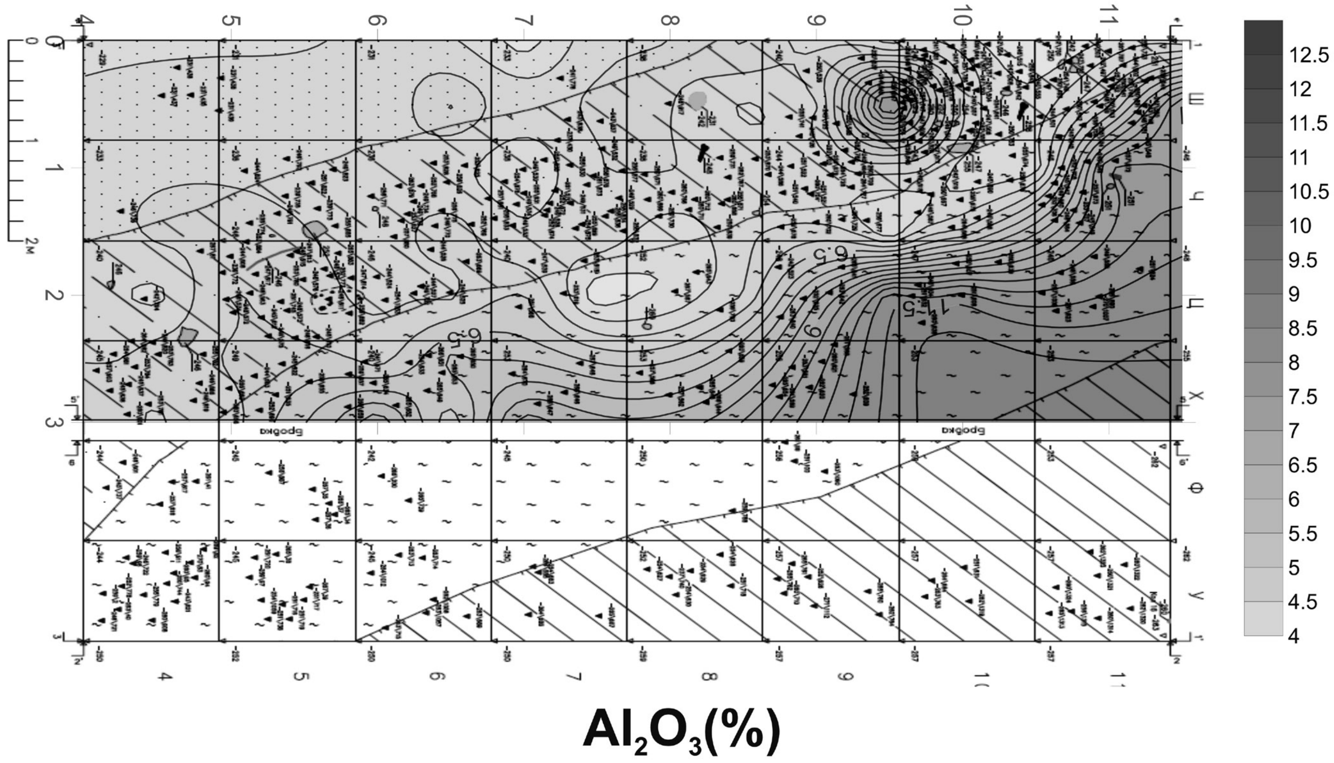

Figure 8. The microrelief map of alumina distribution (%) in the deposits of the Podolije 1 site.

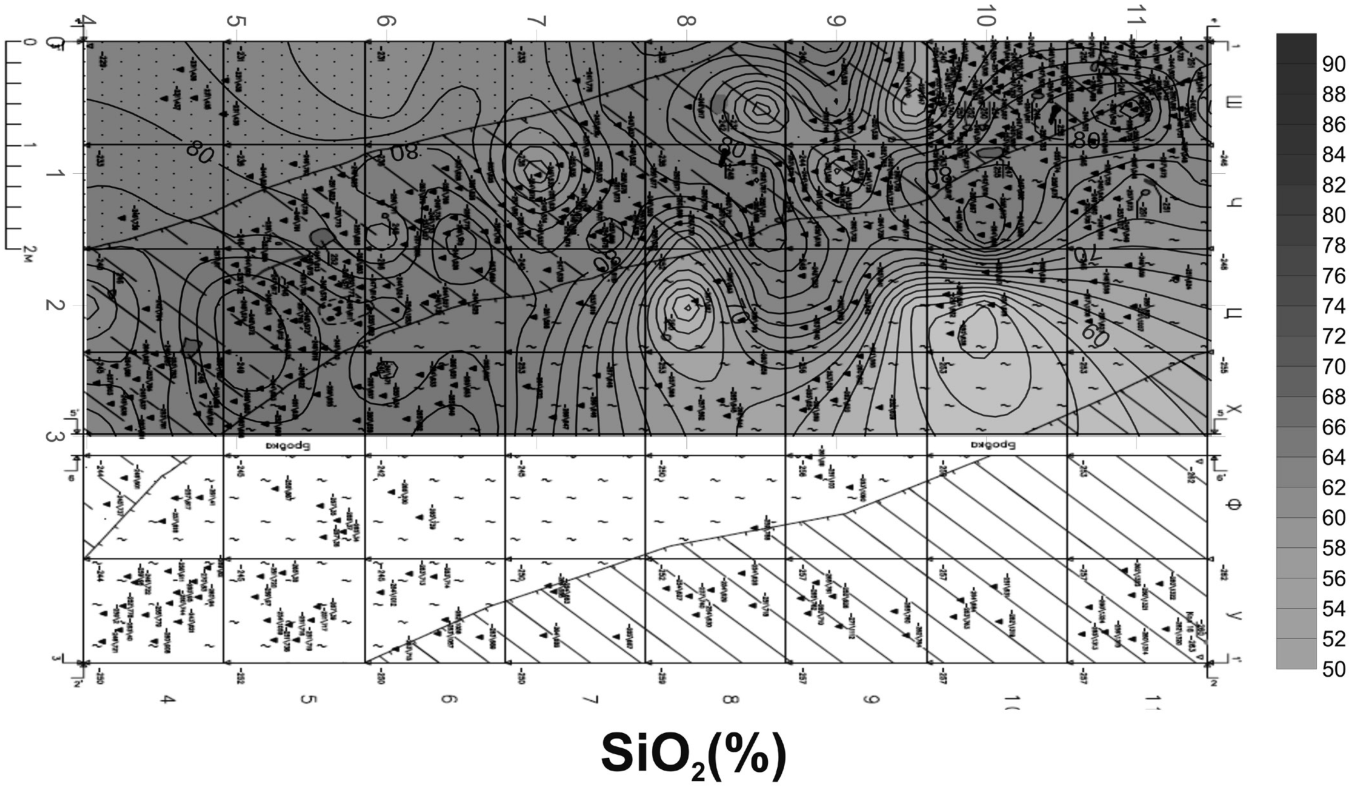

Figure 9. The microrelief map of silica distribution (%) in the deposits of the Podolije 1 site.

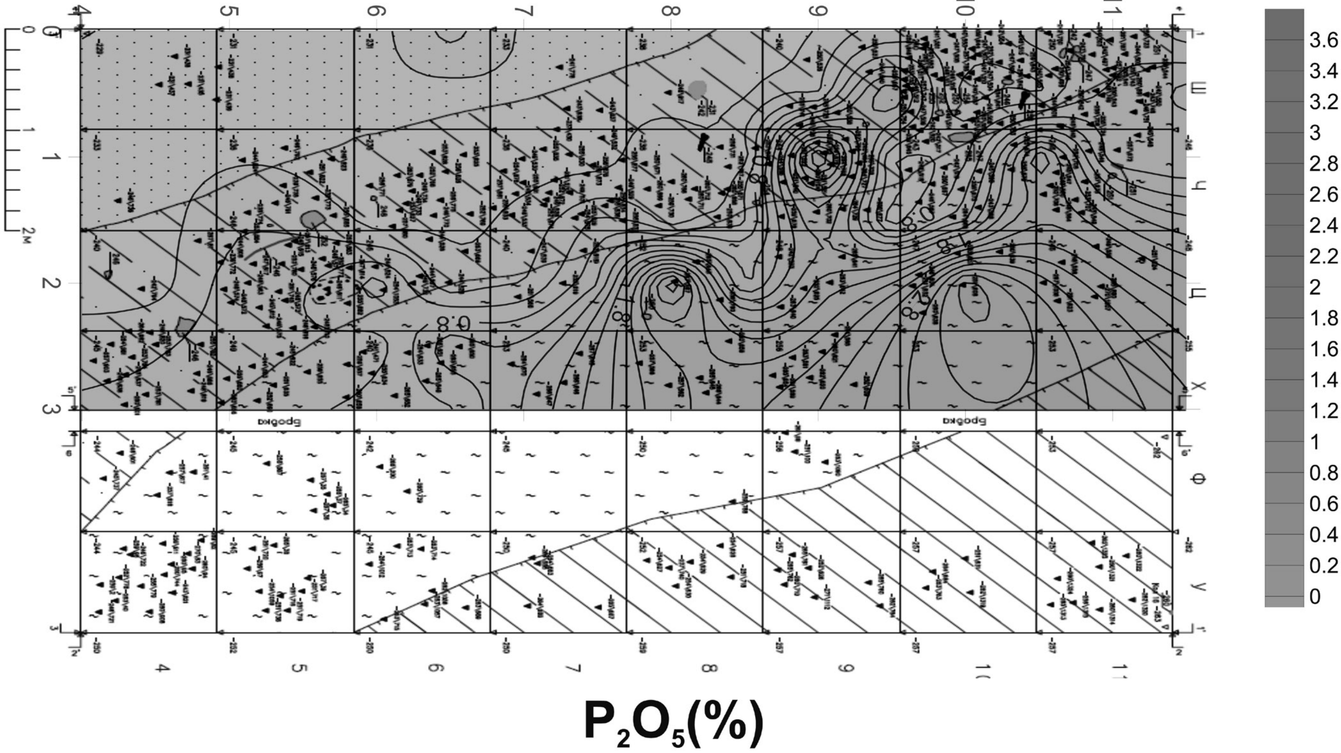

Figure 10. The distribution of phosphorus in the deposits of the Podolije 1 site.

against any significant rewashing of deposits. In the case of the redeposition and transposition of sediments together with artefacts, anomalies in the concentrations of anthropogenic indicators would not be revealed and the deposits would have background-level contents of anthropogenic elements and indicator ratios. The artefacts were found *in situ* in this cultural layer and the geochemical characteristics of the cultural deposits confirm their positions. The data obtained show that the anomalies in the distribution of anthropogenic elements have a good correlation with the remains of the ancient stone construction and the artefact finds (Figures 4 and 5).

The high concentrations of aluminium at the Podolije site were revealed at elevations of the relief that consists of clay loam. Silica is the main component of sand, and its accumulation and high concentrations mark the channel in relief. This indicator marks a depression formed during the ancient channel development. The largest amount of artefacts was found on the sand shore of the channel. There is a good correlation between the altitude of the microrelief, the concentrations of clay and sand sediments, and the alumina and silica distributions. The 3D reconstruction of the microrelief of this place and the correlation with the aluminium distribution is shown in Figure 16.

The distribution maps of anthropogenic components show the anomalies connected with the different functional types of human activity that occurred on the shore of this channel. A high concentration of phosphorus (P2O5, %) (Figure 10) is registered in the big depression in the ancient channel located near the edge of the terrace. In the deposits of the terrace, high concentrations of manganese (Mn), barium (Ba), and iron (Fe) were registered (Figure 11). Their anomalies can be connected with the remains of decaying organics on the slope of the hill. Different materials from the top zone probably accumulated in this part of the terrace as a result of erosion processes.

Anthropogenic calcium is a good marker for several zones located on the shore of the channel. In these zones, various archaeological finds such as stone tools, ceramic sherds, and bones were found. These zones can be interpreted as places in which ancient people could prepare animals and fish (Figure 12). High concentrations of anthropogenic strontium were also registered in these places. Elements such as CaO_{antr}, Sr_{antr}, and P_2O_5 are the main components of the remains of animal and fish bones. The reconstruction of the locations of fish and animal preparation zones is shown in Figure 16.

There are several places in which fireplaces were located. Charcoal and ash were found in these places, and they are characterized by maximally high concentrations of anthropogenic potassium and rubidium (Figures 14 and 15). Several fireplace zones coincide with places of fish and animal preparation, which are marked by CaO_{antr} and Sr_{antr}. The increased concentration of these elements was determined also in some parts of the channel (Figure 16).

The data obtained therefore allows us to determine several zones in the shore part of the terrace. These zones can be interpreted as temporary places used for fishing and animal preparation. These places are situated near hearths that had been used for cooking on the edge of the terrace. In the pit located at the edge of the terrace, most of the waste material was accumulated in processes of sediment rewashing and the erosion of elevated loam hills.

Conclusion

Two different types of functional zones were considered at the Ohkta 1 and Podolije 1 sites occupied by people in ca. 3300 cal BC. At the Okhta 1 site, the data provided by geochemical mapping and distributions of artefacts allows determining the burial place. The burial is characterized by a maximum combination of chemical anthropogenic components such as P_2O_{5antr}, CaO_{antr}, and Fe_2O_3. Another type of distribution of chemical elements was considered at the Podolije 1 site. There were seasonal sites with fireplaces and zones for fishing and animal preparation on the shore terrace of the channel. In the deposits of this site, a combination of anthropogenic elements such as K_2O_{antr}, Rb_{antr}, CaO_{antr}, and Sr_{antr} was defined. The depressions on the shore of the channel located at the edge of the terrace are characterized by anomalies of a set of chemical elements, namely K_2O_{antr}, Rb_{antr}, CaO_{antr}, Sr_{antr}, Mn_{antr}, Ba_{antr}, Fe, and P_2O_{5antr}, which can be interpreted as refuse from the hills. The geochemical indicator combinations from the same lithological context at the Okhta 1 and Podolije 1 sites have different meanings. The burial zone is characterized by anomalies in bioindicators (P_2O_{5antr} and CaO_{antr}), which are the main components of bones and tissues, as well as iron (Fe_2O_3), which was a component of the ochre used during rituals. A geochemical complex including K_2O_{antr}, Rb_{antr}, CaO_{antr}, and Sr_{antr} characterizes fireplaces (K_2O_{antr} and Rb_{antr} are microelements of coals and ash) and zones of fish and animal preparation (CaO_{antr} and Sr_{antr} are elements of bones). In the depressions on

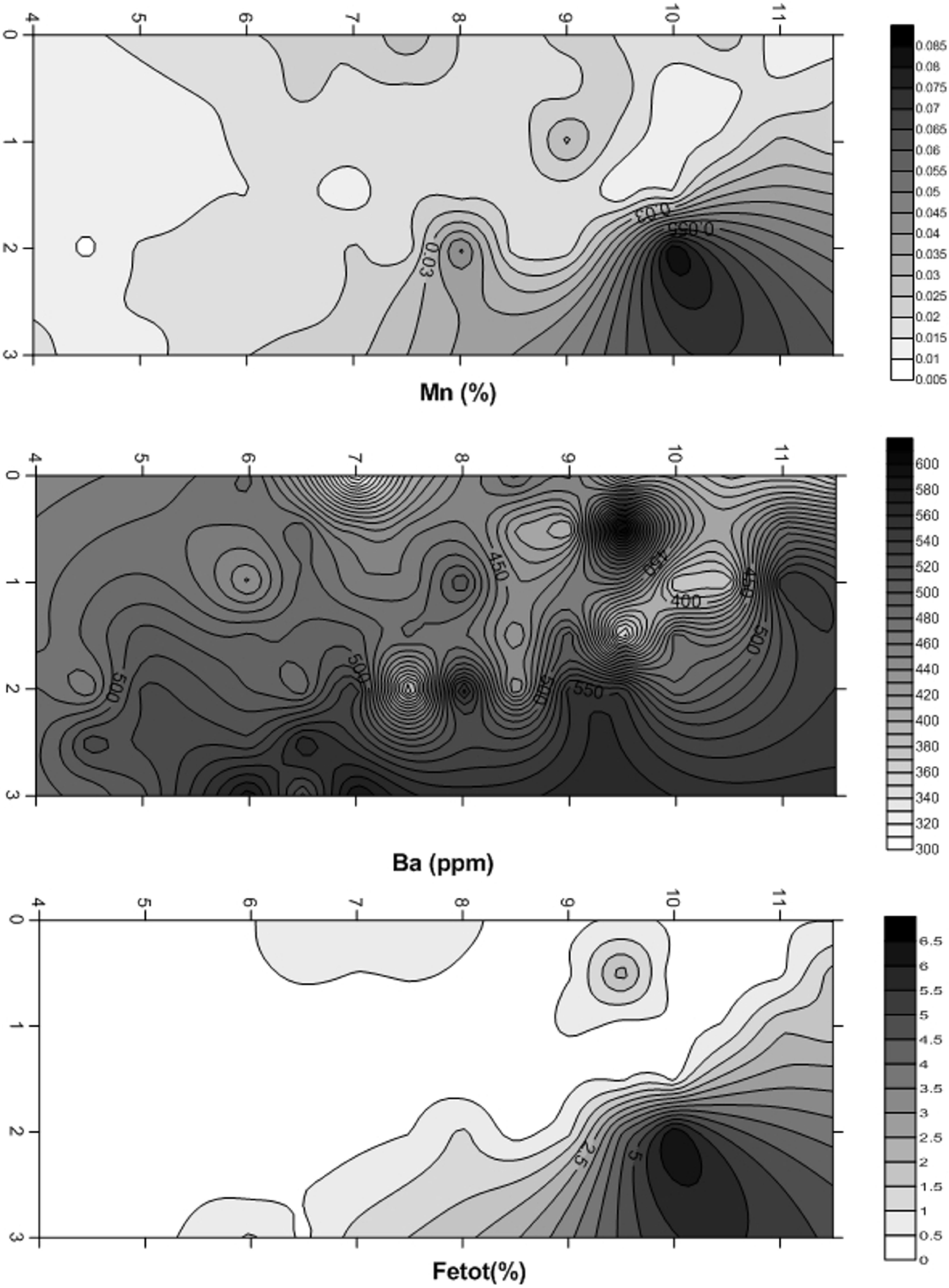

Figure 11. The distribution of manganese (%) barium (%), and iron (%) in the deposits of the Podolije 1 site.

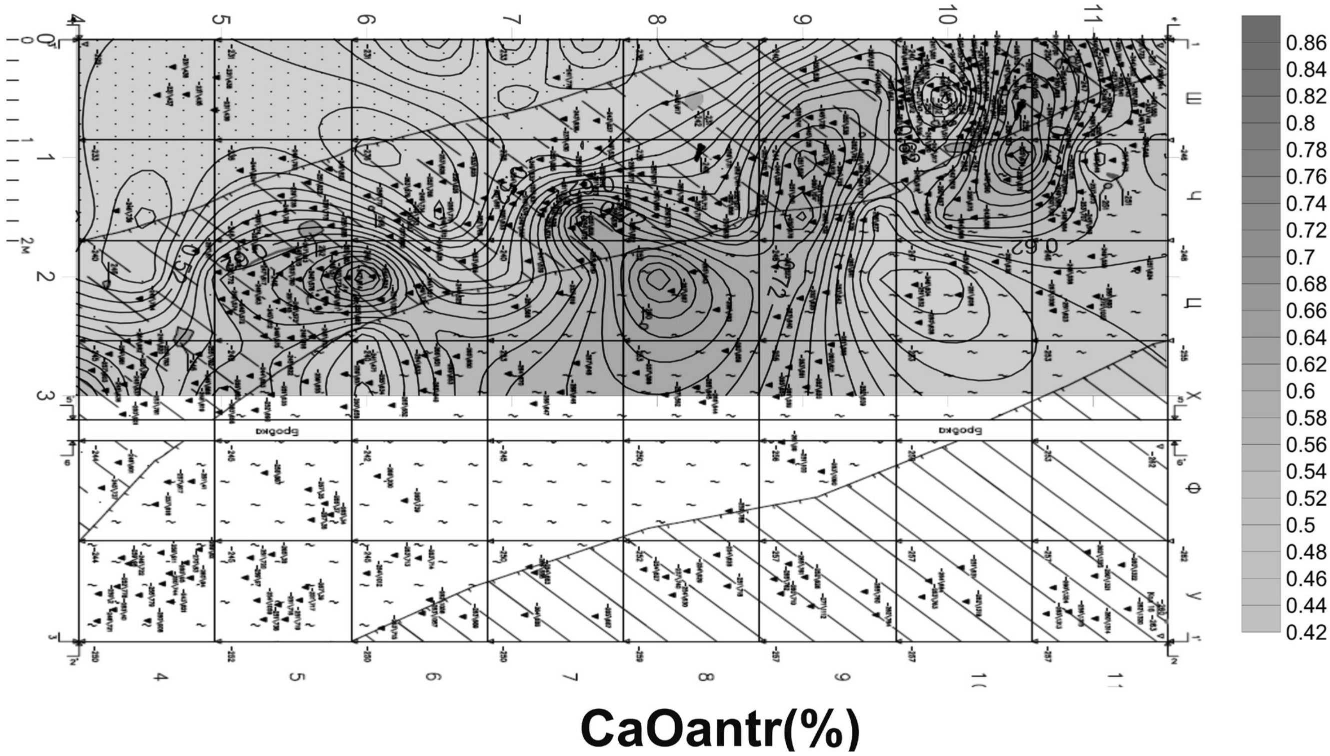

Figure 12. The distribution of CaO_{antr} (%) in the deposits of the Podolije 1 site.

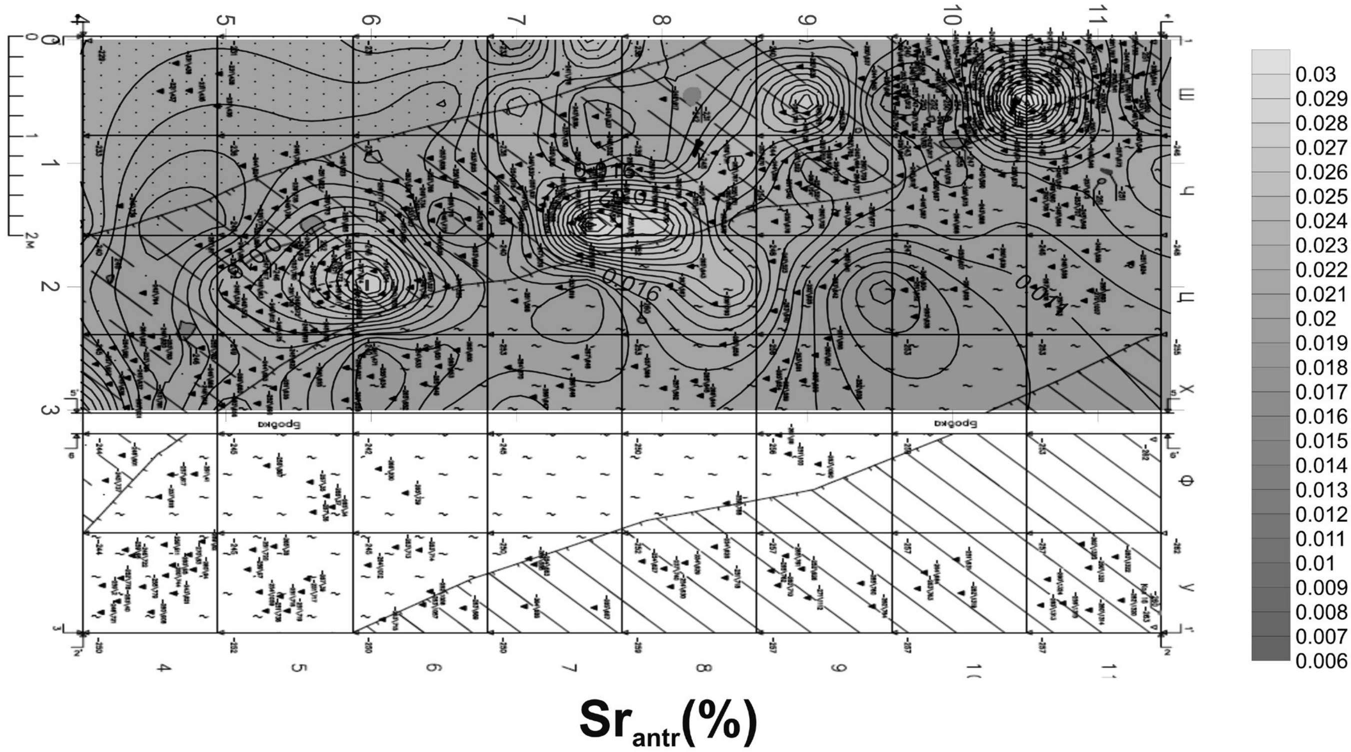

Figure 13. The distribution of Sr_{antr} (%) in the deposits of the Podolije 1 site.

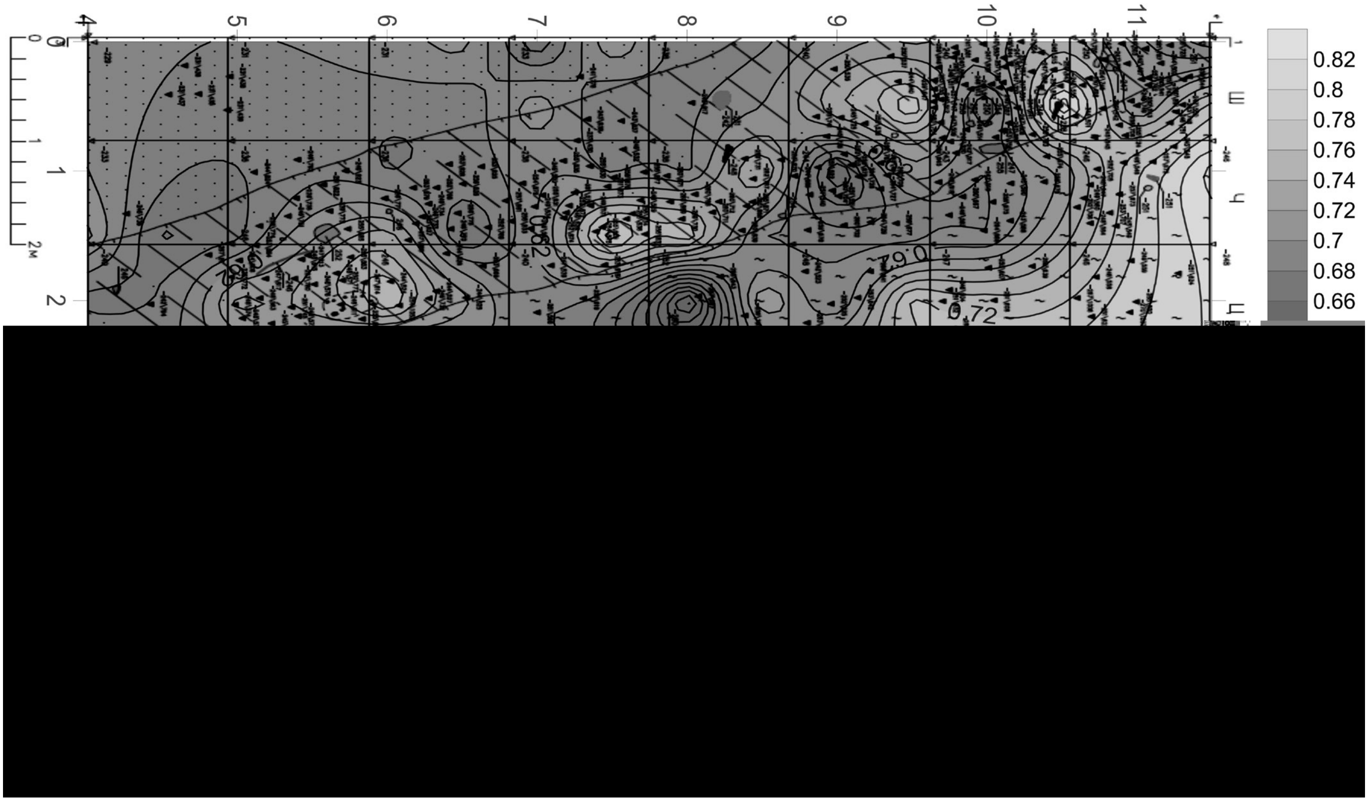

Figure 14. The distribution of K2Oantr (%) in the deposits of the Podolije 1 site.

Figure 15. The distribution of Rbantr (%) in the deposits of the Podolije 1 site.

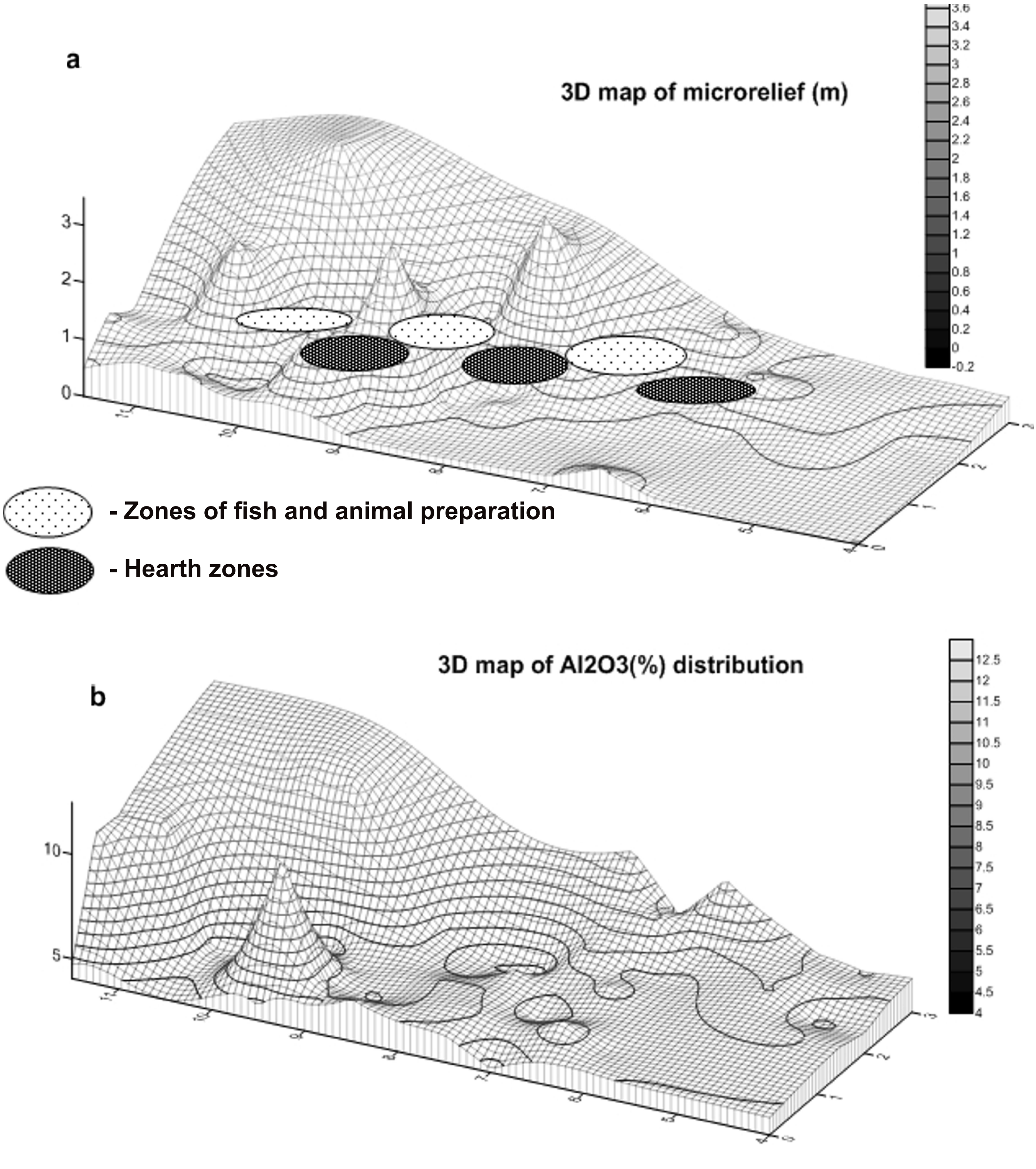

Figure16. The 3D reconstruction of the locations of fish and animal preparation zones (a) and the microrelief on the basis of Al2O3 distribution (b).

the channel shore, material from the hills was found and registered with the help of complex of geochemical indicators: K_2O_{antr} and Rb_{antr} are elements of ash, P_2O_{5antr}, CaO_{antr}, and Sr_{antr} are elements of bones, and Mn_{antr}, Ba_{antr}, and Fe are elements of decayed organics.

The geochemistry of the distribution of main sediment-forming elements, such as alumina (Al_2O_3) and silica (SiO_2), is important for the determination of the ancient microrelief at the site.

The research of archaeological areas by means of geochemical indicator mapping provides an opportunity to assess the functional zones of archaeological sites in more detail. This data allows us to characterize the different types of functional zones and to reconstruct human life at these settlements. These investigations were carried out for the first time in this region, and this method should be applied more widely in Russian archaeology. The development of the multi-element method for the reconstruction of functional zones at sites dating from the Neolithic to the Early Iron Age is important for understanding the activities of ancient people in the territory of Russia and other regions.

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The Studies of Archaeological Bird Remains from Medieval Staraya Ladoga

New Results and Interpretations

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Abstract

This article presents the results of studies of bird remains from medieval Staraya Ladoga, one of the most important medieval cities in the north-western part of Russia. The identification of bird bones from the collection acquired during three years of excavations (2004, 2008, and 2009) at Zemlyanoe gorodishche in Staraya Ladoga revealed the presence of 48 species of birds with a diverse range of wild species (46) in general and the dominance of capercaillie (*Tetrao urogallus*) in particular. The domestic birds in the collection studied are represented by domestic chicken (*Gallus gallus f. domestica*) and domestic goose (*Anser anser f. domestica*). The results of the study reveal another point of great interest, namely the discovery of bones of the razorbill (*Alca torda*), great cormorant (*Phalacrocorax carbo*), and common eider (*Somateria mollissima*), which are valuable for the study of ornithogeography and the history of Fennoscandian avifauna. According to the analysis of the ratio of the number of vertebrate animal remains, birds were very important in the diet of the medieval population of Staraya Ladoga. The composition of identified bird species could indicate the high social and economic status of this medieval proto-city and contribute to the understanding of the interaction between different ethnic groups in the region within the context of human-nature interaction.

Keywords: bird bones, Middle Ages, Staraya Ladoga, Zemlyanoe gorodishche

Introduction

The medieval archaeological site of Staraya Ladoga is located in the Leningrad region, Russia, 125 km east of St Petersburg and 12 km south of the estuary of the Volkhov River, one of the tributaries of Lake Ladoga (Figure 1). Modern Staraya Ladoga consists of a small village and an open-air museum where archaeological and historical research projects are currently conducted. In the Middle Ages, Staraya Ladoga was one of the most important cities in the north-western part of modern Russia. The material culture of Staraya Ladoga revealed significant issues for further studies related to the emergence and development of the medieval population of the region, which resulted in the interaction of Slavic, Scandinavian, and Finnish groups (Rjabinin 1997; Kirpichnikov & Saksa 2002; Uino 2006).

The core part of the archaeological site of Staraya Ladoga, named Zemlyanoe gorodishche, has a cultural layer that dates from the 8th to the 17th century AD (Ravdonikas 1949: 11–2). The archaeological studies of Zemlyanoe gorodishche, which started in the early 20th century, have revealed the existence of a cultural layer of 4–5 meters with various archaeological finds, including remains of vertebrate animals: domestic and wild mammals, birds, and fish.

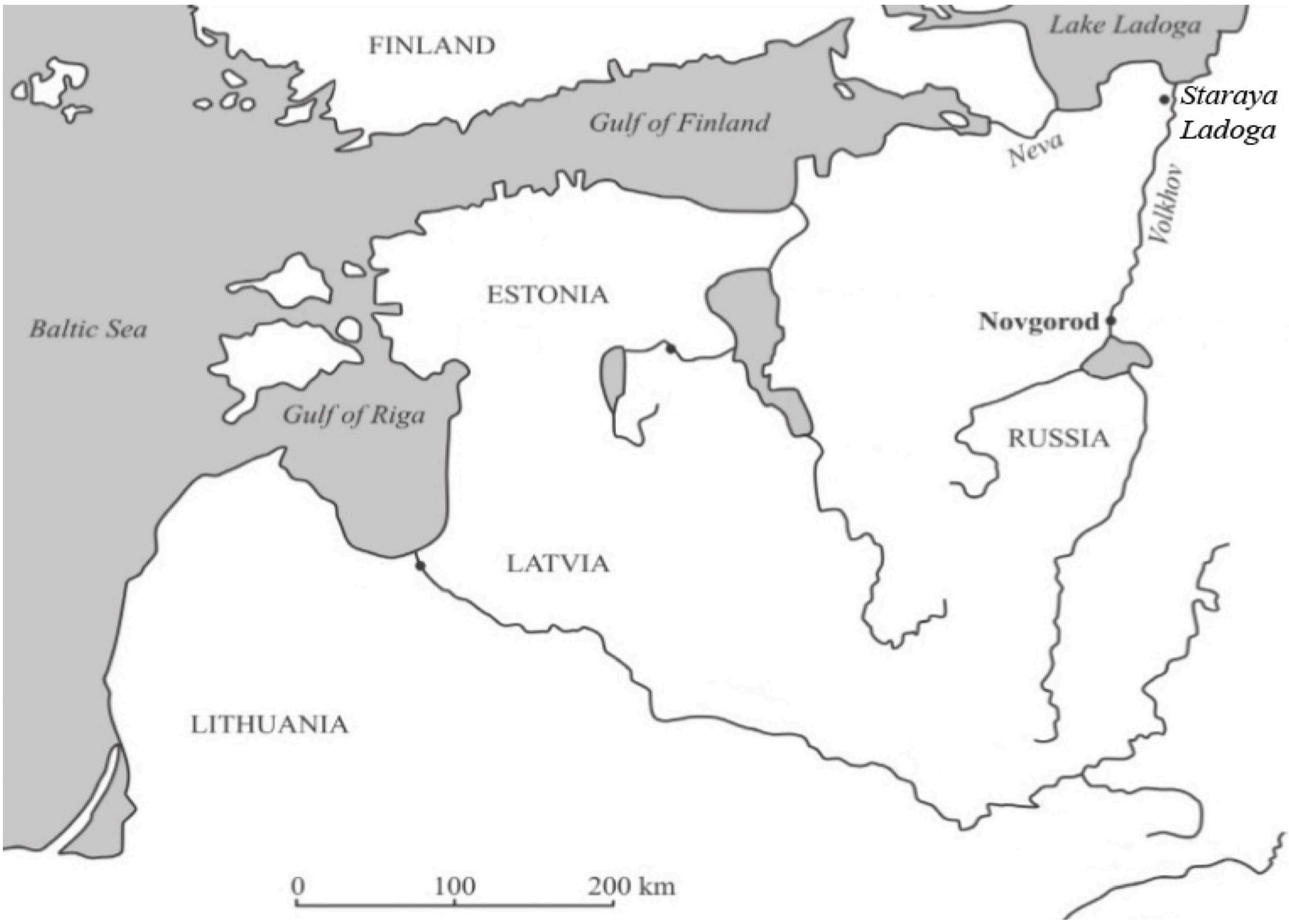

Figure 1. Map of the Eastern Baltic area showing the location of Staraya Ladoga (adapted from Brisbane et al., 2012).

Recently conducted multidisciplinary studies of Zemlyanoe gorodishche in Staraya Ladoga established the appearance of early Slavs in the Lower Volkhov River area as early as in the middle of the first millennium AD. The beginning of the development of the Ladoga settlement was synchronous with the establishment of sea trade communications in the western Baltic area in the 6th and 7th centuries AD. In general, settlement activity in the territory of Staraya Ladoga and the surrounding region, including the territory of Zemlyanoe gorodishche, falls into a period from the 5th century to the first half of the 6th century AD (Kirpichnikov & Kurbatov 2014: 129–130). According to the latest studies, the beginning of the formation of the cultural layer and the burial of the soil of Zemlyanoe gorodishche can be dated to the 8th to 9th centuries AD (Aleksandrovskii et al. 2013: 96–7).

This article presents the results of a new study of bird remains found during the excavations of Zemlyanoe gorodishche in 2004, 2008, and 2009.

Previous studies of bird remains from Zemlyanoe gorodishche

A large number of vertebrate remains, including bird bones, were recovered in the medieval layers of Staraya Ladoga. Data on their species and quantitative composition was first published by Vladislav Ravdonikas, who supervised the excavations in Staraya Ladoga from 1938 to 1947 (Ravdonikas 1949). The archaeological bird remains found during the excavations conducted at the site in 1938–1939 and 1957 were further identified by the specialists of the Institute of Zoology of the USSR Academy of Sciences. According to the results of these studies, the bird remains were found in the layers of the 9th–10th centuries AD and included 665 bird bones attributed to 23 species (Ravdonikas 1949: 51–3) (Table 1). As regards the species composition, the majority of the identified bones belonged to the Galliformes: capercaillie, black grouse, and domestic chicken (with a predominance of wild species). Among the waterfowl species present in this sample, mallard and eider (*Somateria sp.*) were dominant, and the remains of whooper swans, birds of prey, and common ravens were identified as well. Ravdonikas (1949: 50) pointed out the abundance and high level of diversity of wild bird remains in the studied collection of archaeological remains of wild fauna. On the other hand, he neither conducted any further analysis of the dimensional characteristics and anatomical structure of the remains nor discussed the possible significance of birds for the medieval population of Staraya Ladoga.

The partial data on the species composition of birds from the excavation of Staraya Ladoga in 1957 can be found in the tremendous work of Nikolai Vereshchagin and Oleg Rusakov on the Ungulates of the North-Western USSR (1979). The authors admit that the identified 125 bird bones from the excavation are attributed to domestic chicken, black grouse, capercaillie, and ducks without further species identification (Vereshchagin & Rusakov 1979: 29).

The archaeozoological collections of animal remains obtained during the excavations of Staraya Ladoga in 1988–1991 were studied by Aleksei Kasparov (Kasparov 1997). He diagnosed the mammal bone remains and provided data on the total number of fish and bird remains. The materials originate from the 9th and 10th centuries AD. Most of the remains belonged to domestic

Table 1. The results of identifications of bird bones from Zemlyanoe gorodishche of Staraya Ladoga in 1938–1939 (Ravdonikas, 1949: 51–53). NISP - number of identified specimens.

Taxa	**NISP 1938**	**NISP 1939**	**NISP Total**
Greylag goose (*Anser anser*)	-	1	1
Whooper swan (*Cygnus cygnus*)	-	6	6
Anser sp.	1	-	1
Mallard (*Anas platyrhynchos*)	14	46	60
Common teal (*Anas crecca*)	1	1	2
Gadwall (*Anas strepera*)	-	1	1
Eurasian wigeon (*Anas penelope*)	-	4	4
Northern shoveler (*Anas clypeata*)	2	2	4
Anatinae not identified to species	25	2	27
Aythya sp.	2	-	2
Common goldeneye (*Bucephala clangula*)	-	16	16
Somateria sp.	-	34	34
Goosander (*Mergus merganser*)	-	3	3
Aythynae not identified to species	-	6	6
Northern goshawk (*Accipiter gentilis*)	-	3	3
Rough-legged buzzard (*Buteo lagopus*)	-	2	2
Buteo sp.	1	-	1
Golden eagle (*Aquila chrysaetos*)	1	1	2
Falconiformes not identified to species	-	2	2
Black grouse (*Tetrao tetrix*)	28	66	94
Capercaillie (*Tetrao urogallus*)	105	150	255
Hazel grouse (*Bonasa bonasia*)	-	2	2
Domestic chicken (*Gallus gallus f. domestica*)	26	65	91
Galliformes not identified to species	-	31	31
Ruff (*Philomachus pugnax*)	-	1	1
Eurasian woodcock (*Scolopax rusticola*)	-	1	1
Common raven (*Corvus corax*)	1	1	2
Not identified	11	-	11
Total	218	447	665
Number of species	11	20	

mammals. The total number of bird bones with no further identification of the species was 117, which significantly exceeded the total number of wild mammal bones (see Kasparov 1997: 27, Table 1). Kasparov notes that the presence of a large number of bird remains of different sizes indicates active hunting and the widespread practice of breeding domestic chickens, the remains of which are present in the collections (Kasparov 1997: 30).

Unfortunately, no other information on the bird remains found during the archaeological studies of Staraya Ladoga is currently available.

Materials and methods

The majority of the bird bones used for this study were found at excavations # 3 (in 2004) and # 4 (in 2008 and 2009) at Zemlyanoe gorodishche by an excavation team supervised by Dr Anatoly Kirpichnikov. As regards the methodology of the research, it should be highlighted that all bone remains, including bird bones, were collected by hand and had a common archaeological context and dating. The descriptions of the archaeozoological collection from the excavations at Zemlyanoe gorodishche in 2008 and 2009 were prepared by N.E. Bobkovskaya (Institute of Plant and Animal Ecology, Russian Academy of Sciences). She identified the mammal bones and estimated the total number of the fish and bird remains (Bobkovskaya 2008; 2009). After this, we conducted the species identification and detailed research of fish (see Galimova et al. 2015) and bird bones at the Biomonitoring Laboratory (Institute for Problems in Ecology and Mineral Wealth, Tatarstan Academy of Sciences).

The following radiocarbon datings were obtained from wood samples from the 4-m-thick cultural layer, including the studied remains: 1360 ± 50 BP (LY-5462, radiocarbon laboratory of the Research Institute of Geography of St Petersburg University) and 1300 ± 25 BP (Le-7317, radiocarbon laboratory of the IIMK RAS), that is, 660–780 cal AD (Aleksandrovskii et al. 2009: 277). The AMS dating of two bone fragments of Ladoga ringed seal *(Pusa hispida ladogensis)* provides the following dates: 1428 ± 25 BP (Hela-3825), that, is, 585–656 cal AD, and 1545 ± 24 BP (Hela-2824), that is, 427–570 cal AD (Oinonen 2016). The data was calibrated in the program OxCal v. 4.3.2, using the IntCal13 calibration curve.

The further identification of bird remains was based on recommendations and methods developed by D. Serjeantson (2009) and supplemented with a comparative analysis with the skeletal collection of the Biomonitoring Laboratory. All measurements were taken according to the standards by A. von den Driesch (1976: 103–129). The systematic list of the scientific names of birds in Table 1 and Table 2 were taken from the Checklist of the Birds of the Russian Federation (Koblik et al. 2006).

The reconstruction of the wing length of subfossil capercaillie and common eider was based on the linear regression equation $y = a*x +/- b$ (Figure 2 and Figure 3) constructed separately for male and female individuals according to data on the humerus and wing length of modern capercaillie (inhabiting the woodlands of the European part of modern Russia) and the modern common eider (inhabiting the White Sea and Baltic Sea regions). The further comparison of the wing bones of modern and subfossil capercaillie was

Table 2. The list of species of birds from excavations of Zemlyanoe gorodishche in 2004, 2008 and 2009. NISP - number of identified specimens.

Taxa	NISP				NISP percentages
	2004	2008	2009	Total	%
Black-necked grebe/Horned grebe (*Podiceps nigricollis/Podiceps auritus*)	-	1	-	1	0.1
Great Cormorant (*Phalacrocorax carbo*)	-	1	-	1	0.1
Black stork (*Ciconia nigra*)	6	-	-	6	0.4
Barnacle goose (*Branta leucopsis*)	-	2	-	2	0.1
Greylag goose (*Anser anser*)	-	6	-	6	0.4
Domestic goose (*Anser anser f. domestica*)	-	25	9	34	2.5
Greylag/ Domestic goose (*Anser anser/A. anser f. domestica*)	-	1	2	3	0.2
Greater white-fronted goose (*Anser albifrons*)	4	3	2	9	0.7
Lesser white-fronted goose (*Anser erythropus*)	-	7	-	7	0.5
Bean goose (*Anser fabalis*)	1	11	4	16	1.2
Whooper swan (*Cygnus cygnus*)	-	4	-	4	0.3
Bewick's swan (*Cygnus bewickii*)	-	3	-	3	0.2
Anser sp.	1	8	1	10	0.7
Mallard (*Anas platyrhynchos*)	1	210	6	217	15.8
Mallard/Northern pintail (*Anas platyrhynchos/A. acuta*)	-	2	1	3	0.2
Mallard/Northern pintail/ Gadwall (*Anas platyrhynchos/A. acuta/A. strepera*)	-	10	-	10	0.7
Common teal (Anas crecca)	-	20	-	20	1.5
Gadwall (*Anas strepera*)	-	9	1	10	0.7
Eurasian wigeon (*Anas penelope*)	1	38	2	41	3.0
Northern pintail (*Anas acuta*)	-	50	2	52	3.8
Northern pintail/Gadwall (*Anas acuta/A. strepera*)	-	1	-	1	0.1
Garganey (*Anas querquedula*)	-	8	-	8	0.6
Northern shoveler (*Anas clypeata*)	-	37	4	41	3.0
Anas sp.	-	4	1	5	0.4
Common pochard (*Aythya ferina*)	-	6	-	6	0.4
Tufted duck (*Aythya fuligula*)	-	4	1	5	0.4
Greater scaup (*Aythya marila*)	-	1	1	2	0.1
Greater scaup/Tufted duck (*Aythya marila/ A. fuligula*)	-	-	1	1	0.1
Long-tailed duck (*Clangula hyemalis*)	-	5	-	5	0.4
Common goldeneye (*Bucephala clangula*)	-	-	3	3	0.2
Common eider (*Somateria mollissima*)	-	5	-	5	0.4
Smew (*Mergus albellus*)	-	6	-	6	0.4
Red-breasted merganser (*Mergus serrator*)	-	7	-	7	0.5
Goosander (*Mergus merganser*)	1	70	-	71	5.2
Merganser sp.	1	-	-	1	0.1
Northern goshawk (*Accipiter gentilis*)	5	1	-	6	0.4
Eurasian sparrowhawk (*Accipiter nisus*)	1	1	-	2	0.1
Common buzzard (*Buteo buteo*)	-	1	1	2	0.1
White-tailed eagle (*Haliaeetus albicilla*)	1	34	1	36	2.6
Merlin (*Falco columbarius*)	-	-	1	1	0.1
Willow grouse (*Lagopus lagopus*)	-	1	5	6	0.4
Black grouse (*Tetrao tetrix*)	7	92	7	106	7.7
Capercaillie (*Tetrao urogallus*)	5	275	32	312	22.7
Hazel grouse (*Bonasa bonasia*)	-	-	1	1	0.1
Domestic chicken (*Gallus gallus f. domestica*)	7	191	27	225	16.4
Galliformes not identified to species	-	1	-	1	0.1
Lesser black-backed gull (*Larus fuscus*)	-	2	-	2	0.1
Common gull (*Larus canus*)	-	1	-	1	0.1
Common tern (*Sterna hirundo*)	1	-	-	1	0.1
Razorbill (*Alca torda*)	-	2	-	2	0.1
Ural owl (*Strix uralensis*)	-	-	1	1	0.1
Common magpie (*Pica pica*)	1	4	-	5	0.4
Spotted nutcracker (*Nucifraga caryocatactes*)	-	-	1	1	0.1
Eurasian jackdaw (*Corvus monedula*)	-	2	-	2	0.1
Hooded crow (*Corvus cornix*)	15	4	9	28	2.0
Common raven (*Corvus corax*)	-	5	5	10	0.7
Total identified to species	57	1155	126	1338	97.4
Total bird bones	59	1182	132	1373	100
Number of species	15	40	24	47	

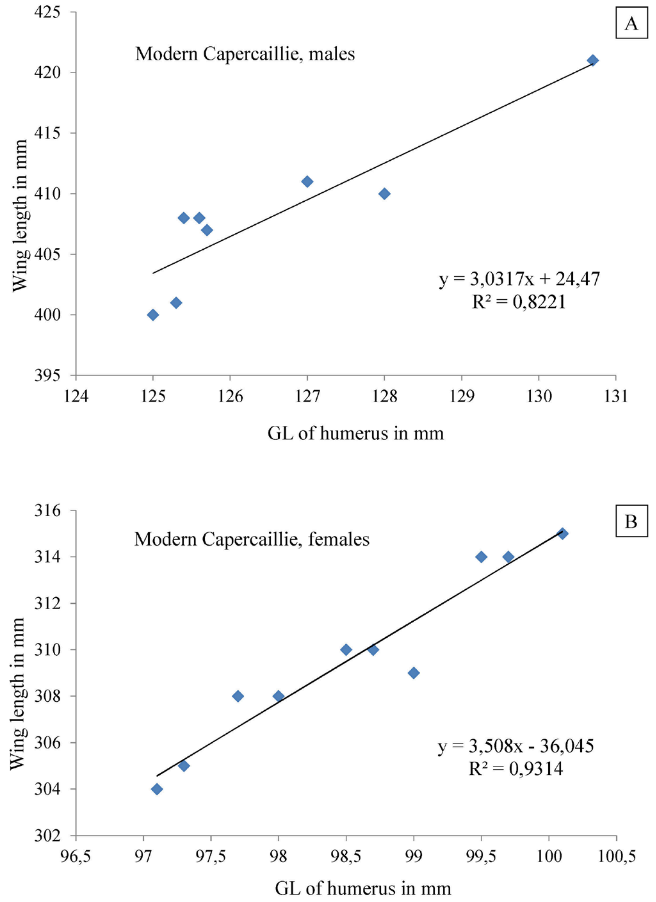

Figure 2. The linear regression according to data on the greatest length (GL) of humerus and wing length of modern capercaillie separately for males, n=8 (A) and females, n=10 (B).

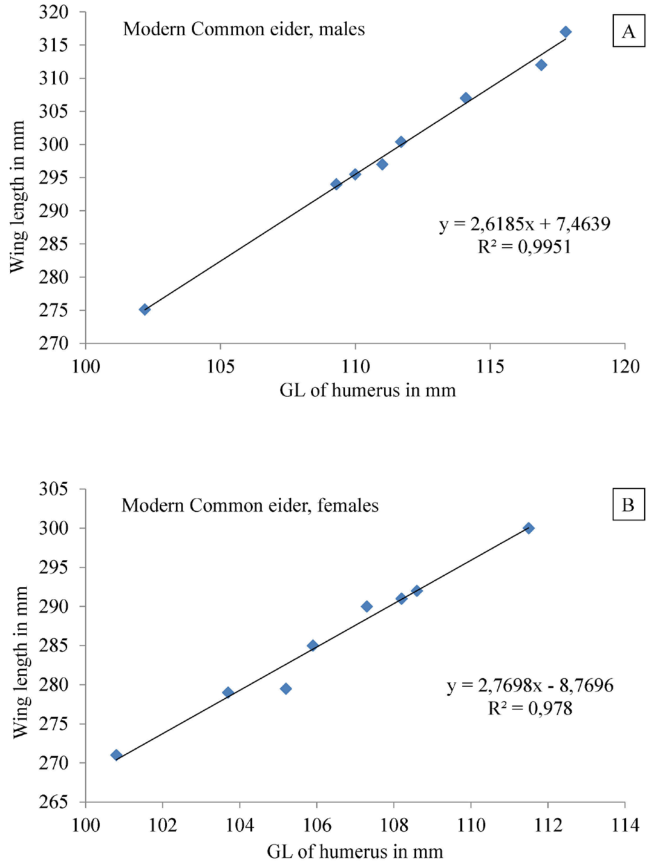

Figure 3. The linear regression according to data on the greatest length (GL) of humerus and wing length of modern common eider separately for males, n=8 (A) and females, n=8 (B).

conducted based on the nonparametric Mann–Whitney U test with an accepted critical level of significance of 0.05 (Zar 2010).

The size comparison of the coracoid of a subfossil razorbill from Staraya Ladoga with that of a modern razorbill was based on the measurements of a modern razorbill from the White Sea population (the collection of the Biomonitoring Laboratory) and the zoological collections of the Natural History Museum of Helsinki (the required data was kindly provided by Dr Henry Pihlström). The reconstruction of the wing length of the subfossil razorbill was also conducted according to the linear regression equation $y = a*x + b$ (Figure 4) constructed on the ratio of the wing lengths and coracoid lengths of modern adult razorbills.

Results

The total number of bird bones (NISP) from all three years of excavations (2004, 2008, and 2009) was 1373. Of these, 1,338 were identified as belonging to 48 species, 46 of which were wild and two domestic (Table 2). It is interesting that the wild species constitute 80.6% of all bird bones studied. Due to the good state of preservation of the bones, all bird bones are identified. The following species dominate the assemblage: capercaillie (22.7%), domestic chicken (16.6%),

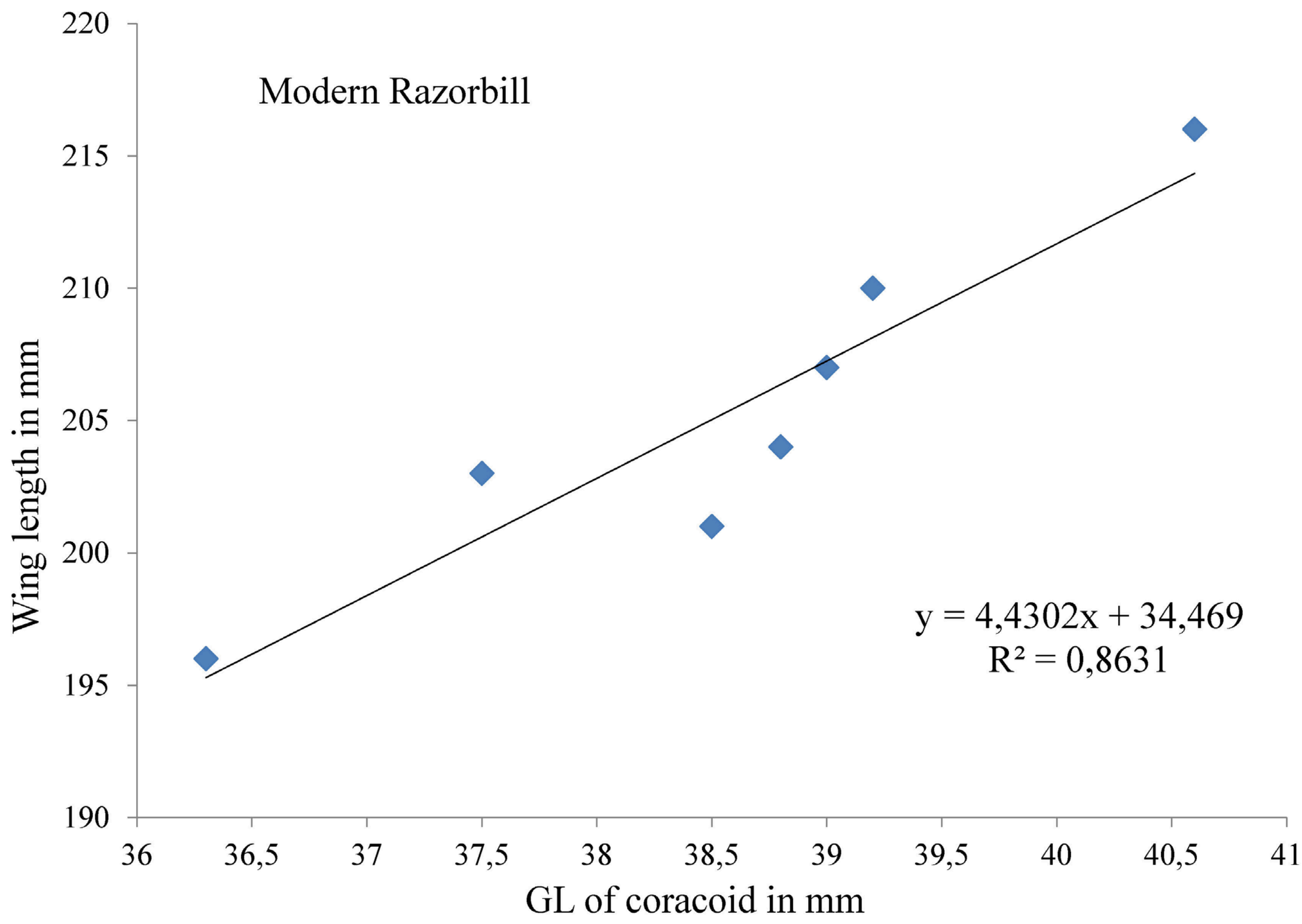

Figure 4. The linear regression according to data on the greatest length (GL) of coracoid and wing length of modern razorbill (without separation by sex), n=7.

Table 3. The number of bird bones (NISP) and the number of species according to order.

Taxon	NISP	Number of species	% species
Podicipediformes	1	1	2.1
Pelecaniformes	1	1	2.1
Ciconiiformes	6	1	2.1
Anseriformes	580	24	51.1
Falconiformes	47	5	10.6
Galliformes	650	5	10.6
Charadriiformes	6	4	8.5
Strigiformes	1	1	2.1
Passeriformes	46	5	10.6
Total	1338	47	100

mallard (16.4%), black grouse (7.7%), and goosander (5.2%). As regards the number of species, the Anseriformes are dominant with 24 species represented (Table 3).

The ratio of the numbers of bird, fish, and mammal bones from Zemlyanoe gorodishche in 2008 and 2009 was as follows: the total number of vertebrate animal bones found during these two years was 36,215 (19,127 bones in 2008 and 17,088 bones in 2009). The remains of mammals (56.5%) prevailed, dominated by domestic species. In second place, fish remains made up 39.3% of the bone finds (Bobkovskaya 2008; 2009). According to our data, bird remains made up 3.6% of all vertebrate animals (1314 bones). It should be noted that the number of bird remains was greater than that of wild mammal bones, the proportion of which was 0.9% of all vertebrate animal remains.

Domestic birds

The domestic birds in the collection studied are represented by domestic chicken and domestic goose.

As regards domestic chicken, 225 bones belonging to this species were found. The collection included all age groups with a predominance of adults (80.8%). However, the amount of bones of immature individuals was relatively high (11.6%). It should be mentioned that among the bones suited for determining the sex, the majority is attributed to male individuals. The main skeletal elements are present, including wing (ulna, humerus) and limb (femur, tibiotarsus), with limb elements dominating (Table 4; Appendix 1). Seven bones of adult chickens (humerus, femur, tibiotarsus) contain medullary bone.

Moreover, an almost complete skeleton of one adult cock was identified (Figure 5), with the bones of the head, carpometacarpus, vertebrae, and phalanges apparently lost during the process of excavation and material collection. Its other bones are in a good state of preservation in complete anatomical order with no traces of cutting identified.

The comparison of minimum, medium, and maximum values of the greatest lengths (GL) of the humerus, femur, and tibiotarsus of adult chicken bones (without separation by sex) found in Staraya Ladoga revealed similarities with the limb size of chicken bones found in the medieval city of Bilyar (dating from the 10th century to the first part of the 13th century AD and located in the Middle Volga region, Russia) (Biomonitoring laboratory data) and medieval Novgorod the Great (dating to the 11th–13th centuries AD, north-western Russia) (see Gorobets & Kovalchuk 2016: 13, Table 18) (Figure 6 B and C). At the same time, the humerus length of chickens from Staraya Ladoga was less than that of chickens from Novgorod the Great (Figure 6 A).

Compared to domestic chicken, the bones of domestic goose are present in smaller numbers. A total of 34 bones were found, making up 13.1% of the poultry remains found during excavations in 2004, 2008, and 2009. This distribution is considered to be typical for the majority of archaeological sites of the 8th to 11th centuries AD (Hamilton-Dyer 2002: 103, Table 1; Askeyev et al. 2013: 121–2, Figure 2; Gorobets & Kovalchuk 2016: 5, Table 3, 4, 6). The bones of domestic geese from Staraya Ladoga belong mainly to adult individuals. However, subadult and juvenile geese are also infrequently present. As regards skeletal elements, the humerus, pelvis, and

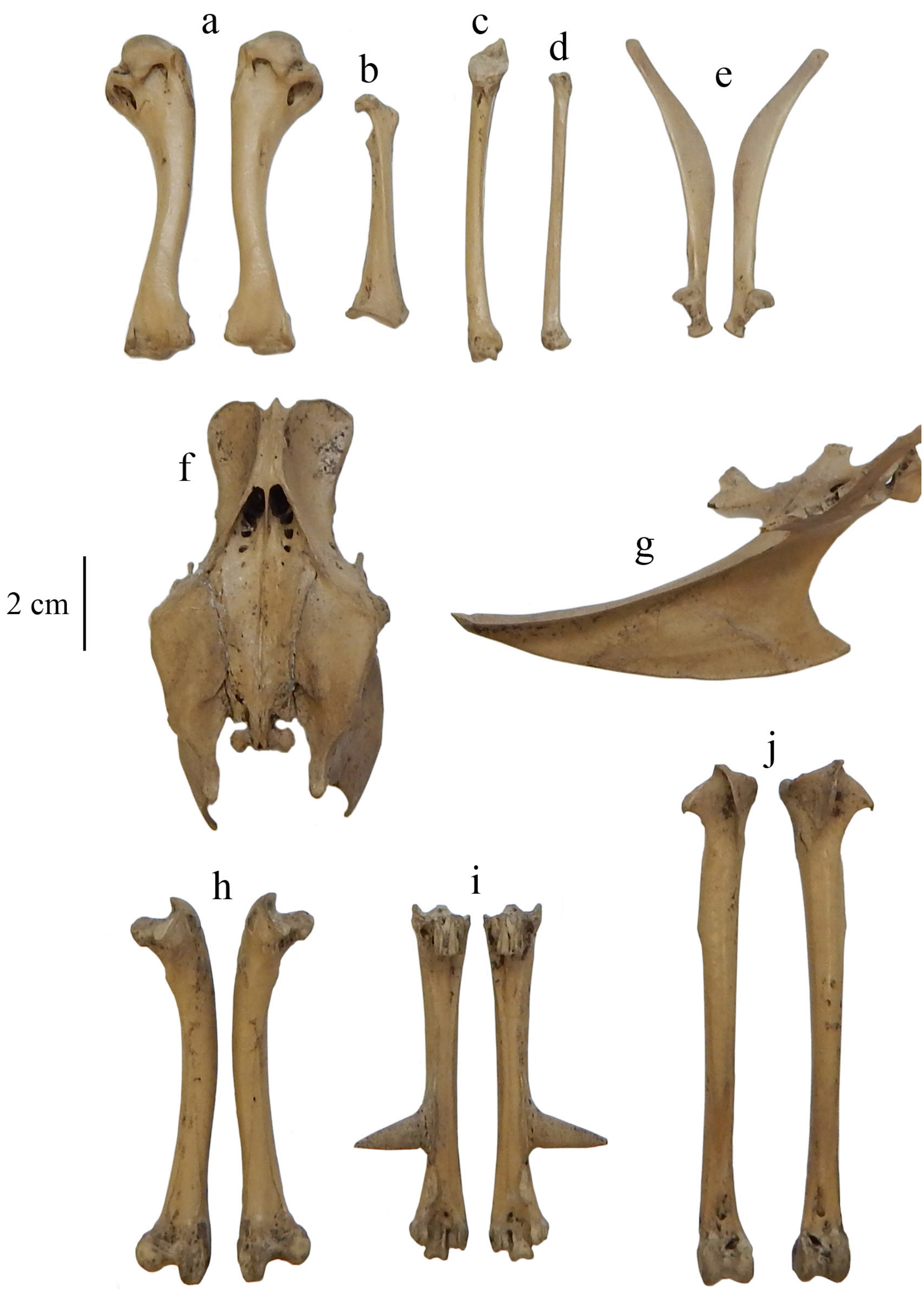

Figure 5. The skeleton of an adult cock from Staraya Ladoga (excavation # 4 of Zemlyanoe gorodishche): a – humerus (right and left), b – coracoid (left), c – ulna (left), d – radius (left), e – scapula (left and right), f – pelvis, g – sternum, h – femur (right and left) , i – tarsometatarsus (right and left) , j – tibiotarsus (left and right). Photo: Dilyara Shaymuratova (Galimova)

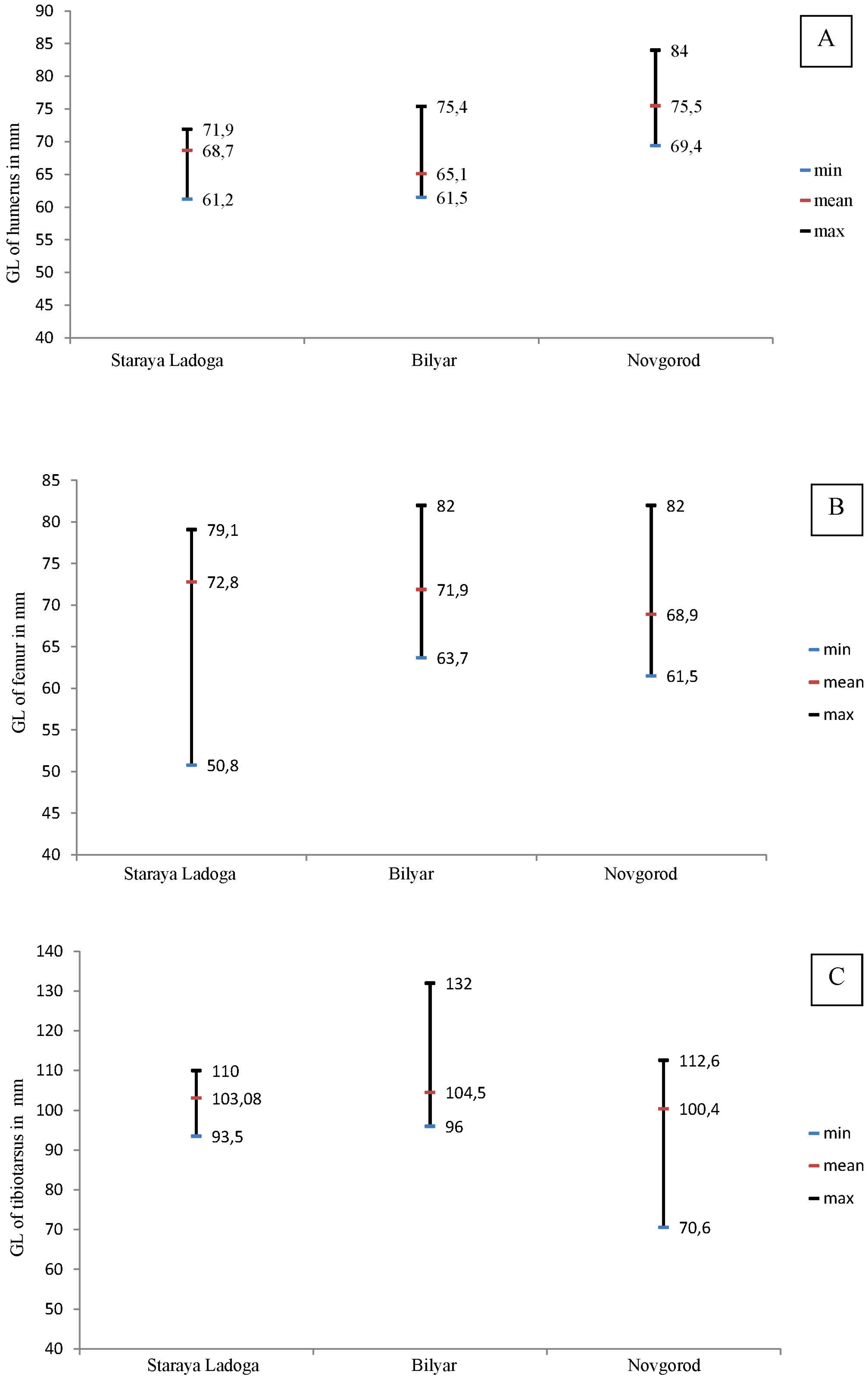

Figure 6. The minimum, medium, and maximum values of the greatest length (GL) measurements of the humerus (A), femur (B), and tibiotarsus (C) of adult domestic chickens (without separation by sex) from the archaeological sites of Staraya Ladoga (humerus n=8; femur n=9; tibiotarsus n=10), Bilyar (humerus n=14; femur n=11; tibiotarsus n=8), and Novgorod the Great (humerus n=12; femur n=17; tibiotarsus n=18).

Table 4. The number of identified specimens (NISP), minimum number of individuals (MNI) with sex distribution, age distribution and prevailing elements of the skeleton of capercaillie and domestic chicken from Zemlyanoe gorodishche (in 2004, 2008, 2009).

Taxa	NISP of taxa	MNI of taxa	Age (NISP; % total NISP)	The dominant elements of the skeleton (NISP; % total NISP)
Capercaillie	312	Male – 81 Female – 24 Sex n.d. – 1 Total – 106	Adult – 305; 98.1% Subadult – 4; 1.3% Subadult-adult – 2; 0.6%	Coracoid – 34; 10.9% Humerus – 39; 12.5% Ulna – 23; 7.4% Femur – 34; 10.9% Tibiotarsus – 23; 7.4%
Domestic chicken	225	Male – 23 Female – 19 Sex n.d. – 61 Total – 103	Adult – 181; 80.8% Subadult – 12; 5.4% Immature – 26; 11.6% Age unknown – 5; 2.2%	Humerus – 31; 13.8% Ulna – 27; 12.1% Femur – 24; 10.7% Tibiotarsus – 46; 20.5%

tibiotarsus dominate the assemblage (Appendix 1). Among the domestic goose bones, one femur has medullary bone.

Wild birds

The most numerous wild bird species in the collection studied is capercaillie, which is also typical of the collection acquired from the excavations in 1938–1939. Most of the bones of this species belong to large adult males. Only two age groups of capercaillies were identified, with adult birds predominating (Table 4). It is therefore suggested that the predominance of large male capercaillies indicates intentional hunting for these birds on leks.

Most key elements of the capercaillie skeleton are present, with wing and leg elements dominating (Table 4). The Mann-Whitney U test showed that capercaillie from Staraya Ladoga had a similar humerus length and wing length as modern capercaillie from the woodlands of the European part of modern Russia (humerus length: p=1 for females, p=0.11 for males; wing length: p=0.9324 for females, p=0.05186 for males). The ratio of the greatest humerus length (GL) of to the smallest diaphysis width (SC) of capercaillie from Staraya Ladoga (Table 5) shows no difference compared to measurements taken from modern capercaillie (Figure 7 A), which allows us to conclude that the size of capercaillie in medieval Staraya Ladoga was similar to the size of modern birds.

Birds of prey

There are six species of birds of prey in the studied collection: white-tailed eagle, northern goshawk, Eurasian sparrowhawk, common buzzard, merlin, and Ural owl.

Another interesting find in this category is an almost complete skeleton of an adult female white-tailed eagle (25 bones) (Appendix 1). The statement that all 25 bones originate from one specimen is based on the fact that they were found in one location in anatomically correct order and had a similar colour and structure of bone tissue. No cut marks were found on the bones. Thus, we assume that the bird died a natural death. The wing bones (carpometacarpus) and leg bones (tibiotarsus) of this individual have pathological changes. Both carpometacarpi have a pathological proliferation of bone tissue in the proximal part of the bone (Figure 8 C), which made it difficult

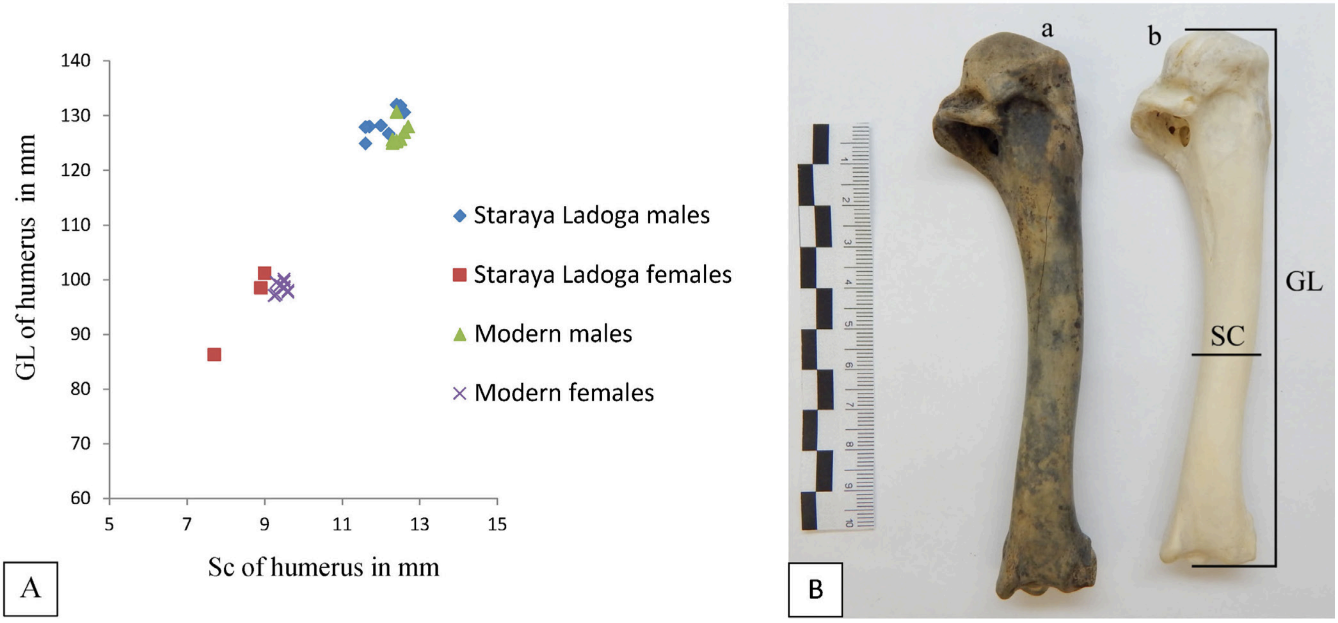

Figure 7. A: The ratio of the greatest length (GL) of humerus (Y axis) to the smallest width (SC) of diaphysis (X axis) of capercaillie from Staraya Ladoga and modern capercaillie from the European part of modern Russia. B: The humerus (right) of subfossil capercaillie (a) and modern capercaillie with measurements (b). Photo: Dilyara Shaymuratova (Galimova)

Figure 8. The tibiotarsus (A, B - from different sides, left tibiotarsus with pathology) and carpometacarpus (C) of white-tailed eagle with pathological changes indicated by arrows. > Figure 8. The tibiotarsus (A, B - from different sides, left tibiotarsus with pathology) and carpometacarpus (C) of white-tailed eagle with pathological changes indicated by arrows. Photo: Dilyara Shaymuratova (Galimova)

Table 5. Bone measurements and reconstruction of wing length of capercaillie, razorbill and common eider from Zemlyanoe gorodishche of Staraya Ladoga.

Greatest length (GL), mm	Smallest breadth of the diaphysis (SC), mm	The reconstruction of wing length, mm
Humerus of Capercaillie (males)		
124.9	11.6	403.1
130.6	12.6	420.4
126.7	12.2	408.6
132	12.4	424.7
128	11.7	412.5
128.2	12	413.1
127.9	11.6	412.2
131.8	12.5	424.0
Humerus of Capercaillie (females)		
98.5	8.9	309.5
101.2	9	319.0
86.3	7.7	266.7
Coracoid of Razorbill (males/females)		
36.3	4.2	195.3
Humerus of Common eider (male)		
113.4	7.4	304.4

to move the wing. This growth is typical for old birds and leads to a significant change affecting the flight abilities of the bird. On the lower part of the diaphysis of the left tibiotarsus (Figure 8 A and B), an overgrown fracture with subsequent formation of a large bone callus was identified. Due to this trauma, the entire leg became shorter and, apparently, had lost its functional activity. The movement of the bird was hindered. Based on these pathological changes in the skeleton, we assume that this individual lived in a settlement: perhaps it was kept captive in an enclosure for some purpose or was a scavenger in local garbage dumps. The traumas would not allow it to survive in nature.

The collection studied includes the remains of other white-tailed eagle individuals as well: 11 bones from 7 individuals. The northern goshawk and Eurasian sparrowhawk bones identified belong to adult individuals, which may indicate hawking or cult birds (Prummel 1997: 335–8; Serjeantson 2009: 321–3; Bochenski et al. 2016: 661–9).

The predominance of white-tailed eagle, northern goshawk, and Eurasian sparrowhawk bones among the total number of birds of prey found at Staraya Ladoga is a feature common to European medieval settlements with a high social status in the modern United Kingdom (Yalden & Albarella 2009: 134–49), Poland (Bochenski et al 2016: 661–9), Ukraine (Gorobets & Kovalchuk 2016: 6–14), north-western Russia (Hamilton-Dyer 2002: 104; Zinoviev 2011: 280, Table 1; Gorobets & Kovalchuk 2016: 4, Table 2; Hamilton-Dyer et al. 2016: 6–7, Table 6), and the Middle Volga region of Russia (Askeyev et al. 2013: 119–120, Table 1, 135).

Corvids

The presence of bones of representatives of the Corvidae family should be noted: the bones of the common magpie, spotted nutcracker, Eurasian jackdaw, hooded crow, and common raven were found, with a relatively large number of hooded crow and common raven bones among them (Table 2; Appendix 1). It is significant that the crow and raven bones do not have any cut marks. As regards the quantity and species composition of corvids from Staraya Ladoga, there are several similarities with the bird remains found at Viking settlements in Denmark (Gotfredsen 2014: 369, Table 2).

Bones of rare bird species: the most interesting findings

The greatest finding of this study is the discovery of razorbill, great cormorant, and common eider bones (Table 2; Appendix 1). The coracoid (Figure 9) and scapula fragment of one adult razorbill female were identified. A cleavage of the coracoid has medullary bone, indicating that the bird was hunted during its nesting period. There is also a cut mark fixed on the diaphysis of the coracoid. As regards the measurements of the razorbill coracoid from Staraya Ladoga (Table 5), they are similar to the measurements of modern razorbills inhabiting the White Sea region and to the measurements of individuals from the Natural History Museum in Helsinki. According to the reconstruction conducted using the methodology mentioned above, the length of the wings of the subfossil razorbill is 195.3 mm. One humerus (fragment) from the collection from Staraya Ladoga belongs to a great cormorant. Although only one bone of

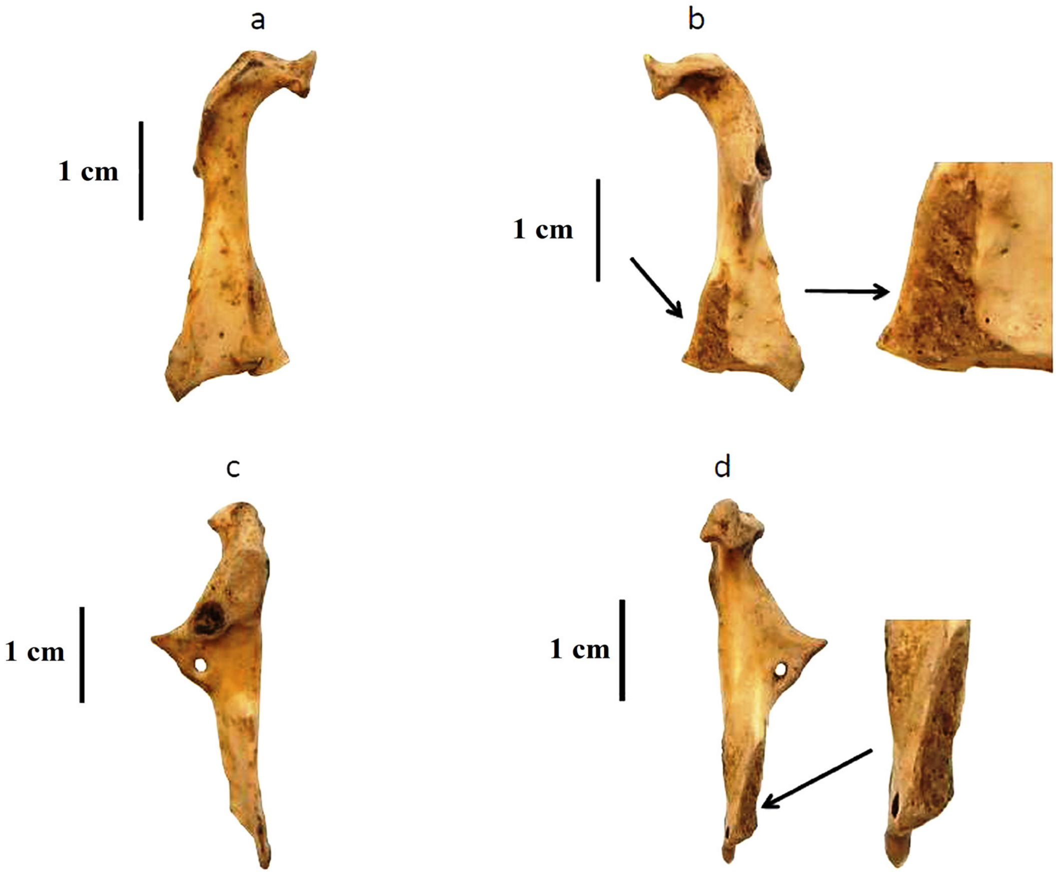

Figure 9. The razorbill coracoid (right) from Staraya Ladoga (excavation # 4 of Zemlyanoe gorodishche) from different sides: a – external, b – internal, c - outer side, d - inner side. The medullary bone is indicated with arrows. Photo: Dilyara Shaymuratova (Galimova)

Figure 10. The common eider humerus (left) from Staraya Ladoga (excavation # 4 of Zemlyanoe gorodishche). A and B - different sides of the bone. Photo: Dilyara Shaymuratova (Galimova)

this species was found, it could indicate that the cormorant was not uncommon in the area around the southern shore of Lake Ladoga.

Five bones of the common eider were also identified in the collection (Appendix 1; Figure 10). The reconstructed wing length of the subfossil common eider is 304.4 mm (Table 5). The reconstructed length is similar to the wing length of a modern common eider from the Baltic Sea and White Sea populations.

Discussion

One of the features revealed by the analysis of species diversity and quantity of archaeological bird remains from Zemlyanoe gorodishche is the similarity of these finds to characteristics obtained from similar studies conducted at the following medieval settlements: Idnakar (9th–13th centuries AD, the Republic of Udmurtia, Russia) (Bogatkina & Kalyakin 2005: 281–6; Ivanova & Zhurbin 2006: 74) Krutik (9th–10th centuries AD, Vologda region, Russia) (Andreeva 1991: 186), and Rodanovo (9th–11th centuries AD, Perm region, Russia) (Panteleev 2012: 728). Such similarities in the composition, in our opinion, may be caused by several reasons. Firstly, all of the above-mentioned settlements were located in a boreal area characterized by a similar composition of eastern European taiga avifauna (Sazonov 2004: 73–148).

Secondly, the dominance of capercaillie and black grouse among the archaeological bird remains found at the above-mentioned medieval settlements could reflect the substantial use of these species by the medieval population as a food resource available all year round. According to calculations of the total biomass of vertebrate animals in the boreal area of the European part of Russia, the biomass of tetraonids amounts to 26–42 kg per square kilometer. This is approximately equal to the biomass of wild ungulates, namely Eurasian elk (*Alces alces*) and reindeer (*Rangifer tarandus*) (Semenov-Tian-Shansky 1960: 189, Table 54; 302–3).

Thirdly, the diversity of wetland and aquatic species identified was due to the location of these settlements in the vicinity of bird habitats and migration routes, namely in the valleys of major rivers and lakes. It is possible that the hunting of these birds increased seasonally during mass migration periods.

All of the medieval settlements mentioned above had a predominantly Finno-Ugric population that probably had common traditions and ways of human-nature interaction, as well as common beliefs and food preferences. In this context, the absence of the remains of some species of birds or their small amount in the collections may be attributed to the fact that the killing of such species was prohibited. For instance, this has a parallel in the traditions of the Finnish medieval population, among which it was prohibited to kill cranes and swans, whereas the hunting of grouse birds was permitted (Vinokurova 2007: 20–3).

The species composition of birds found during the excavations of Staraya Ladoga may indicate the multi-ethnic composition of the medieval human population of this settlement and its neighbourhood. Namely, the broad diversity of aquatic bird species (ducks) and the large number of domestic chicken bones is considered to be a feature of medieval East Slavic cities (Maltby 2013: 239–40, 243, Appendix 1; Gorobets & Kovalchuk 2016: 11, Table 15; Hamilton-Dyer et al. 2016: 6–7, Table 6). At the same time, the relatively large amount of corvid bones may indicate the presence of Scandinavian ethnic groups in Staraya Ladoga, as it is known that these birds had a sacred meaning for the medieval population of Scandinavia (Gotfredsen 2014: 371–2). Moreover, the large number of bones of forest game birds, such as capercaillie, allows us to assume that the Finnish population might have played the role of supply agents of these species to Staraya Ladoga and to consider that the Finnish ethnic group was present as residents in this settlement. It is necessary to emphasize that the abundance of capercaillie bones is a feature of medieval and post-medieval settlements in Finland (Puputti 2006: 19, Table 1; Tourunen 2008: 269, Table 30; Nurminen 2013a: 3–4; Nurminen, 2013b: 3-4; Salmi et al, 2014: 494, Table 1; Kivikero, 2015: 20, Table 24). On the contrary, the remains of capercaillie are rarely found at Slavic medieval settlements (Gorobets & Kovalchuk, 2016; Hamilton-Dyer et al. 2016).

The identification of the bones of birds of prey and corvids in the collection may indicate an urbanized area with a high accumulative capacity. A large medieval settlement like Staraya Ladoga, surrounded by a variety of natural landscapes, could naturally accumulate a number of faunal remains, including various species of wild birds. The early urbanization of a certain territory leads to the formation of a large amount of human food waste. This attracts various bird species that could be fed by these dumps, whereas predatory species also use these places for hunting corvids and other birds (Mulkeen & O'Conner 1997: 446).

The presence of the bones of wild birds that were neither eaten nor hunted may therefore reflect the accumulation effect caused by direct or indirect human activities.

Although the amount of poultry bird bones in the studied collection is 3.5 times smaller than the amount of bones of wild species, their presence, as well as the presence of juvenile domestic chicken bones, may indicate that the medieval population could breed chickens locally in Staraya Ladoga. A similar trend has already been noted at medieval urban settlements in western Europe (Clavel 2001: 108–10; Serjeantson 2006: 131–44; Thys & Van Neer 2010: 81). At the same time, the presence of domestic goose bones in the collection could be sufficient evidence of the successful breeding of this species in the period studied. However, the small amount of goose remains may indicate the minor significance of this species in the diet and economy of the medieval population of Staraya Ladoga.

The discovery of razorbill and common eider bones in the collection of Staraya Ladoga is quite interesting from the point of view of zoogeography. Ilmari Hilden collected data on the breeding of razorbills in the north-western part of Lake Ladoga (Hilden 1921a: 56; Hilden 1921a b: 61–2, 218–9). This data is then used to complete the verification of a number of review articles and monographs devoted to the avifauna of the USSR, Finland, Karelia, and north-western Russia (Dementev, 1951: 176; Merikallio 1958; Neufeldt 1958: 246; Malczewski & Pukinsky 1983: 228–9). Based on this data, Irena Neufeldt believed that auk birds formed a relict bird fauna in Lake Ladoga in the late Neolithic (Neufeldt 1958: 246). Starting from the 1960s, scientific articles began to question the accuracy of the information obtained by Ilmari Hilden in 1920 on the presence of razorbills and other auks on Lake Ladoga (see review Pihlström 2015: 14–6). The recent publications show a lack of data on razorbill breeding on the islands of Lake Ladoga, and no data is provided on migrant and vagrant individuals in this region (Cherenkov et al. 2016: 208). We discuss the existence and possibility of breeding razorbills on Lake Ladoga. According to recent scientific understanding, there are no biological or ecological obstacles to the breeding of auk birds, including razorbill, in freshwater and brackish-water ecosystems. The absence of these birds in the modern ecosystem of Lake Ladoga is likely due to human activity (Pihlström 2012: 332).

As regards common eider, it is necessary to note that until the end of the 20th century, it was commonly thought that this species rarely migrated to Lake Ladoga. However, during the last decade, there has been an increase in the number of migrating and nesting birds of this species in the region (Waltho & Coulson 2015: 66). The common eider bones identified in the collection suggest that this species was quite common on the southern shore of Lake Ladoga, as well as on the lower reaches of the Volkhov River.

Conclusions

An analysis of the ratio of the numbers of vertebrate animal remains allows us to conclude that the residents of Staraya Ladoga in the 9th–10th centuries AD practiced the breeding of domestic mammals and domestic chickens, as well as fishing and wild bird hunting. Birds were of great importance in the diet of the medieval population of Staraya Ladoga. The presence of several hunting grounds, including vast forests and wetlands, around this medieval proto-city gave rise to the high diversity of wild species found in the collection.

The discovery of the bones of razorbill, great cormorant, common eider, black stork, and barnacle goose is quite important for ornithogeography and the study of the history of Fennoscandian avifauna, allowing us to track several changes in the ranges of these species over the last 1500 years.

The convenient location of Staraya Ladoga on the flyways of migratory birds, its favourable landscape, its environment, the nearby huge forest areas, and Lake Ladoga and the Volkhov River allowed the population to actively use its natural resources, namely birds, fish, and wild mammals. The diversity of bird species, as well as the various ways of using them, indicates the high social and economic status of this medieval settlement.

The results of this study show the importance of further studies of the animal remains from archaeological sites not only from a biological and economic viewpoint, but also for improving our understanding of the emergence and development of various peoples who inhabited particular areas in the past in general. In particular, the outcomes of this research project on archaeological bird remains from Zemlyanoe gorodishche could contribute to the understanding of the interaction between different ethnic groups in the region within the context of human-nature interaction.

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Appendix 1. The skeleton elements composition of discussed birds from Zemlyanoe gorodishche of Staraya Ladoga (2004, 2008, 2009). NISP – number of identified specimens. MNI – minimum number of individuals.

Taxa	NISP	MNI	Cranium	Qudratum	Maxilla	Mandibula	Coracoid	Furcula	Sternum	Scapula	Humerus	Radius	Ulna	Carpometacarpus	Synsacrum	Pelvis	Femur	Tibiotarsus	Fibula	Tarsometatrsus	Vertebrae	Costae	Phalanx
Phalacrocorax carbo	1	1									1												
Ciconia nigra	6	1									1	1										4	
Anser anser f. domestica	34	19			1	1	2		3	1	8	1	2	1		5	3	4	1	1			
Branta leucopsis	2	1						1			1												
Somateria mollissima	5	4					1		1		3												
Accipiter gentilis	6	2									2	1	1	1						1			
Accipiter nisus	2	2									1		1										
Buteo buteo	2	2											1	1									
Haliaeetus albicilla	11	7					1					1		2			1			1	1		4
Haliaeetus albicilla*	25	1	1				1		1	2	2	1	2	2		1	1	2		1	4	1	3
Falco columbarius	1	1											1										
Tetrao urogallus	312	106	7	1	1	6	34	8	21	15	39	18	23	12	8	17	34	23	2	12	20	8	3
Gallus gallus f. domestica	225	103	2				11	3	22	11	31	13	27	1	1	16	24	46	1	15			
Alca torda	2	1					1			1													
Strix uralensis	1	1												1									
Pica pica	5	5					1				1		1					2					
Nucifraga caryocatactes	1	1									1												
Corvus monedula	2	2				1											1						
Corvus cornix	28	12					1		2	1	5	1	5	1		2	1	5		2	2		
Corvus corax	10	8									1		1	2			1	3		1			1

*** one individual with pathologies**

Geoarchaeology, bedrock surveys, and geochemical analysis

Tracing the provenance of medieval building stones

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Abstract

This study started from the premise that information about the provenance of building materials increases the understanding of construction activities and utilization of environment in the past. In this study, we analyzed 163 building stones from twelve medieval cellars in Turku (Finland) with a portable X-ray fluorescence spectrometer (pXRF) and compared the results with surveys and analysis of the local bedrock. According to the study, the majority of stones were quarried near the construction site. The only exceptions were limestones, which are not of local origin and could have been imported from the Baltic area or collected as glacial boulders on rocky beaches in the surroundings of Turku. Another major result is that stones of different kinds and from different areas were used in the same buildings and rooms. This indicates non-systematic quarrying, reuse of stones and challenges related to the acquisition of material despite the availability of local rocks.

Keywords: building archaeology, Finland, geology, the Middle Ages, pXRF, Turku

Introduction

When Turku was founded in the early 14th century, stone and brick were already known as building materials in this region. According to the present knowledge, bricks and stones were used for the first time in the latter part of the 13th century in the Bishop's Church locating in Koroinen at the distance of about 1.6 km from the present-day Turku Cathedral (Drake 1987; Koivunen 2003; Ratilainen 2016; Ratilainen et al. 2016). In Turku, stones and bricks were first used at the beginning of the 14th century in the construction of administrational and religious buildings, such as cathedral, castle and town hall (Drake 2003a: 129–33; 2003b: 137–8; Uotila 2003: 123–4).

In archaeological excavations, dozens of masonry buildings have been discovered in Turku. However, because of the lack of reliable datings, all buildings cannot be labelled medieval with certainty (e.g., Uotila 2003; 2005; 2007). In the early 18th century, the number of masonry houses in Turku was about 150, but in the Middle Ages the number was probably much smaller (Dahlström 1929: 204, 206; 1947: 20; Seppänen 2012: 670–1). The choice of building materials was influenced by the availability of the material and technical skills, building traditions and housing culture of the constructor. In Turku, the emergence of masonry buildings in the late 14th and in first part of the 15th century seems to relate to the immigration of German burghers and to close contacts with Hanse towns (Uotila 2003: 121–2; 2009: 44; Seppänen 2012: 671–8).

The medieval buildings in Turku have been analyzed and discussed in several studies, but the studies focused on building materials have been more limited (e.g. Uotila 2003; 2009; Seppänen 2012; Aalto 2016). Attention has mainly been paid to limestones, which are not of local origin and easy to detect. Otherwise, only the stones in one foundation have been analyzed more thoroughly. The stones in this construction were granite and gneiss / kinzigite found on the surrounding hills in Turku (Lindberg et al. 1994; Saloranta & Seppänen 2002: 32–3). Because of the availability of quarried stones, boulders and shingles of reasonable size on the shore zone near Turku, the general hypothesis has been that the stones used are of local origin and that the dimension stones were quarried from the surrounding environment (Seppänen 2012: 646). The main aim of this study was to test this hypothesis and to trace the origin of the quarried dimension stones used in the medieval Turku with geological investigations and scientific analyses.

In archeological excavations in the city of Turku, the documentation of constructions and building materials has improved in the course of the past decades but the documentation and analyses related to stones are still insufficient. All studies related to medieval buildings apart from the still standing Turku Castle and Cathedral are based on the preserved evidence from the lower parts and foundations of excavated buildings. Because of limited preservation, our knowledge about the building materials used in the upper floors is very limited. Therefore it is impossible to obtain a full picture of the use of different building materials in the Middle Ages in Turku.

Furthermore, most remains have either been demolished or covered after the excavations and are no longer available for analysis. Besides the castle and cathedral, medieval buildings are still visible for the public in the Aboa Vetus & Ars

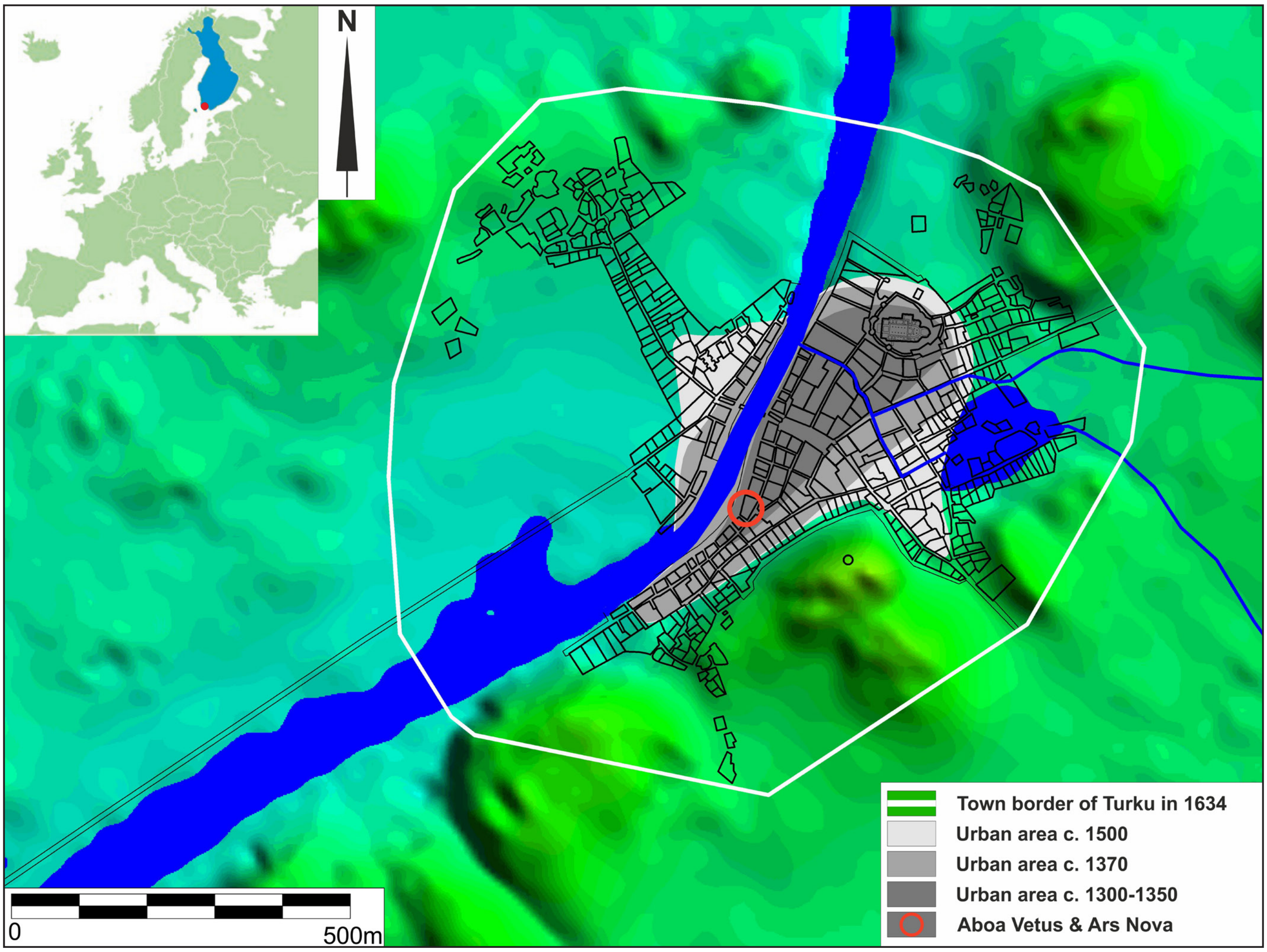

Figure 1. The map presents the town area of early modern Turku with interpretations about urban growth during the Middle Ages. The buildings investigated in this study in the present-day Aboa Vetus & Ars Nova museum located at the southwestern part of the medieval town. The figure contains data from the Elevation model 10 m of The National Land Survey of Finland.

Nova museum where the majority of the remains unearthed in the museum area is still *in situ* as part of the museum interior and exhibition. The largest excavations in this area were conducted in the 1920s and 1990s due to construction activities. The museum complex comprising both archaeological-historical museum Aboa Vetus and contemporary art museum Ars Nova was opened in 1995 (Sartes 2003) (Figure 1). Because of easy accessibility and availability of dated buildings, the study was focused on the remains in the museum. The remains are situated mainly in Aboa Vetus museum and therefore in this study only the name Aboa Vetus is used when referring to the remains in the museum complex.

Another aim of this study was to find evidence about medieval quarrying and quarries in Turku. The only preserved medieval written source referring to quarrying is a donation letter from 1329. In this letter, Turku Cathedral was donated a hill called Krakanes on the island of Kemiö in the vicinity of Turku. According to the letter, the hill had provided lime for the production of mortar (*pro fabrica montem cementi*) needed in masonry building (FMU 369; Seppänen 2012: 651–2).

The earliest information about a quarry in Turku comes from the mid 19th century and refers to Kakola Hill, where coarse grained and light gray coloured granite was quarried for the construction of a jailhouse. According to the place of provenance, this granite is also called kakolite. Today, kakolite is the most common dimension stone used in Turku. Besides Kakola, there were three quarries north of Turku in the 20th century: Räntämäki red granite quarry, Urusvuori (Räntämäki) monzodiorite quarry near Turku Airport and Kuninkoja granite quarry (Härme 1960: 56, 58; Lindberg et al. 1994; Karhunen 2004: 50). Geological bedrock maps, soil maps and historical maps do not reveal any evidence related to quarries in the Turku region.

There are no mentions in historical sources about medieval stonecutters in Turku. Probably, the stonecutters were addressed as masons or even as carpenters before the guild ordinances for professional stonecutters were established in the realm of Sweden in 1601. By 1571, there had been at least thirteen master masons in Turku while five of them were still active (Orviste 1989: 288). In the excavations, no evidence has been found referring to cutting and working of dimension stones on construction sites. This can indicate that the stones were cut near the quarry prior to transportation. The less likely explanation is that there was a specific place for cutting the dimension stones in the town area which has not been found (Seppänen 2012: 646).

The absence of cutting and working waste may also indicate effective reuse of dimension stones, which raises the question of the volume of quarrying activities in Turku. Because of the limited preservation, the quantity of the dimension stones used in medieval buildings cannot be counted, but according to the remains unearthed, the stones were mainly used in the lower parts of the buildings, on the floors and walls of cellars, while the upper parts were made of bricks of possibly even of wood. Furthermore, stones were used in fireplaces, wells and pavements, but the majority of these were probably loose cobbles and boulders collected from the surroundings of the town (Seppänen 2012).

Due to frequent and destructive fires in the Middle Ages, the use of stone and brick was promoted by statutes and recommendations. For example, in the early 15th century Reval, in the present-day Tallinn in Estonia, only brick and stone were permitted as building materials. The prevention of fires was not the only reason for promoting the use of stone and brick. The regulations also aimed at improving the sanitation and increasing the attractiveness of the town. The regulations were probably not equally strict in medieval Sweden although there were recommendations for using stone and brick, and on the other hand, also limitations concerning the use of timber (Johansen & von zur Mühlen 1973: 229; Söderlund 2001: 707; Seppänen 2012: 673–5).

In Turku, the increase in masonry buildings seems to coincide with the decline of good quality timber. Furthermore, the increase of masonry buildings was related to population growth, which is reflected in the expansion of the town area and in the intensification of the building stock. At the same time social and occupational stratification of the townspeople became more visible in Turku (Seppänen 2012: 623–7, 674). Consequently, the studies and analyses related to building materials do not only increase our knowledge about the supply and use of different materials in building activities, but may offer new insights into questions concerning possible professional specialization and organization of the society, as well as environmental changes in the city landscape.

Research material

Medieval buildings in Aboa Vetus

The majority of the medieval buildings in Aboa Vetus and Ars Nova were excavated in the mid 1990s during the building of the museum complex, but small-scale excavations have been carried out ever since. The oldest masonry building in this area is dated to the beginning of the 1390s, while the majority is dated to the fifteenth and sixteenth century. The buildings have a long history including several alterations, enlargements and reconstructions which can be detected in constructions, attachments and plasterings, although the dating of these changes remains problematic. Some of the buildings were deserted and demolished in mid-seventeenth century but parts of a few buildings were used until the early twentieth century.

Mainly the cellars of the buildings are preserved while the evidence of the upper parts is very limited. In general, the lowest parts of the walls were made of stones while the upper parts of the walls were made of bricks. The proportion of bricks to stones is surprisingly large. The limited number of stones and the contamination of surfaces caused by later activities affected the number of analyses in this study. The floors of the cellars were mainly paved with stones, but the time of paving remains unsure, while reconstructions are also possible. Furthermore, the floors were quite often made of cobbles, possibly collected from the surroundings, with no indications of quarrying activities (Sartes & Lehtonen 2007; Seppänen 2012: 692–5). The dating of the cellars is based on dendrochronological analyses of timber foundations and therefore they can be considered quite reliable (e.g. Zetterberg 2003; Sartes & Lehtonen 2007; Uotila 2007; 2009; Savolainen 2011; Aalto 2016).

Since the focus of this study was in the medieval buildings, only twelve cellars with reliable datings to medieval period were selected for analysis (Figure 2). A short description of each cellar is provided in the chapter Stone types and the provenance of building materials but the more detailed discussion about the buildings and building materials in this area remains beyond the frames of this article.

Bedrock outcrops in the Turku region

The main aim of this study was to test the pXRF method on building stones and to trace the provenance of medieval building stones in Aboa Vetus area by comparing the stones with the local bedrock. In recent years the complicated geology of the Turku region has been discussed in several studies (e.g. Väisänen et al. 1994; Väisänen & Hölttä 1999; Väisänen 2002; Helenius et al. 2004; Väisänen & Westerlund 2007; Nevalainen et al. 2014). The bedrock of the Turku region consists mainly of older supracrustal (volcanic and sedimentary) rocks and slightly younger plutonic (intrusive) rocks. plutonic (intrusive) rocks. They formed as a consequence of Svecofennian orogeny (the process of formation of mountains) which caused new magma to rise, anatexis (melting) of old bedrock, migmatization, metamorphosis and fluid transportation, which all mixed and changed the original element proportions of the bedrock. Supracrustal rocks (circa 1900 Ma) were originally sediments and eroded volcanogenic material that stratified to the bottom of the shallow sea. They metamorphosed in the heat

Figure 2. The map presents the location of cellars in Aboa Vetus and the number of analyzed stones per each cellar included in this study. All in all, 163 stones were analyzed from twelve cellars. The figure contains data from the excavation maps of the area.

and pressure of the later Svecofennian orogeny. Depending on the composition (mineralogy and chemistry) of the original sediments, they metamorphosed forming quartz feldspar gneiss, mica gneiss or amphibolite common in this region.

Metamorphosed supracrustal rocks are usually fine-grained, strongly foliated and dark-coloured because of the mafic mineralogy. In high temperature and pressure, sediments melted partially or totally (anatexis) and when cooling down they formed migmatites or sedimentary granites (S-type). Furthermore, high pressure and temperature caused the growing of the metamorphic porphyroblasts (large recrystallized mineral grains), usually of garnet and cordierite, which both are abundant in the rocks of southwest Finland. The plutonic rocks consist of older synorogenic (in the same time with orogeny) granitoids (in Turku area 1890–1870 Ma), granodiorites, diorites, tonalities, and younger late-orogenic (1840–1810 Ma) microcline granites. Granitic rocks are usually homogenous, of medium to coarse grain and of light colour. Granitoids have originally crystallized from magma deep in the earth's crust. They are mainly composed of quartz, plagioclase and alkali feldspar whose proportion defines the nomination of granitoids (Karhunen 2004; Kohonen & Rämö 2005).

Analytical methods and instrumentation

Analysis of rocks using pXRF

The portable X-ray fluorescence spectrometer (hereafter pXRF) is an easy and fast device for analysing elements from solid materials. Laboratory analyses for the whole-rock geo-chemistry are usually done from a homogenized (melted, dissolved or pulverized) sample for best results. In stones, the element composition is not homogenous but divided to mineral grains. Consequently, it is easier to get more accurate results by analysing fine grained stones than coarse grained ones. A pXRF-measurement of coarse-grained stones (for example granites with abundant quartz) reveals the chemistry of mineral grains in that part, not the chemistry of the whole stone. Therefore, when analysing a coarse-grained stone one needs to take more than one measurement and calculate the average values of element contents to achieve more reliable information about the geochemistry of that specimen.

Depending on the consistency and region of the specimen, the repeatability or precision of pXRF measurements is usually excellent (often better than ± 10%). On the basis of ten replicate analyses, RSDs (relative standard deviation) for the major elements Fe, Ca, K, and Si has been reported to be less than 2.5 % and for Mn, Rb, Sr, Ti, Y, Zn, and Zr less than 5 %. For low abundance elements (such as Sb, Se and Sn) RSDs can be more than 20 % (Hall et al. 2014: 123). Tests made on obsidian and volcanic rocks have proved that a well-calibrated pXRF device can generate accurate data about elemental composition of rocks, and the conceptual validity of pXRF for provenance studies has also been demonstrated (Newlander et al. 2015). Furthermore, the parallel ICP-AES and pXRF analyses of soil samples have indicated the reliability of pXRF in elemental determination (Rouillon & Taylor 2016: 259–61).

One needs to be aware that the calibration of the pXRF-device and the application used for analysis affect results. In fundamental calibration, as used also in Mining Plus application of Olympus pXRF, the detected element counts and the analysis result of the single element is recorded as ppm (Thomsen 2007; Hall et al. 2013). Measuring or counting time (i.e. radiation time) is an important factor in pXRF analysing, too. For heavier elements the counting time can be from ten to fifteen seconds per beam, but even a few minutes per beam are needed when the intention is to reach as many elements as possible. However, no significant improvement has been recorded in precision and reliability of pXRF data when the counting time is more than 180 seconds (Olympus 2012; Newlander et al. 2015).

Abilities and limitations of the pXRF used in this study

In this study, the geochemical analyses were made with the Olympus Delta DP-6500 portable X-ray fluorescence spectrometer provided for us by the Department of Geography and Geology at the University of Turku. The instrument has a 4W X-ray tube with tantalum/gold-anode and a SDD (Silicon Drift Detector) -photodiode as the detector. The focusing area of radiation (i.e. the area of analysis) is 10 mm in diameter (circa 0.8 cm2). The penetration of radiation depends on the measured material so that for stones, ceramics and bricks it is from hundreds of micrometers to a few millimeters. During each analysis, two different radiation beams/modes are used with Mining Plus application (Innov-X 2005; Olympus 2011; 2016).

The device is capable of detecting the following elements: vanadium, chromium, iron, cobalt, nickel, copper, zinc, hafnium, tantalum, wolfram, arsenic, lead, bismuth, zirconium, molybdenum, silver, cadmium, tin, antimony, titanium, manganese, aluminium, silicon, phosphorus, sulphur, chlorine, potassium, and calcium. In this case study, it was impossible to use calcium analyses because the stones in the buildings were covered with mortar and plaster, which would have affected the measurements of this element. Unfortunately, the pXRF device at our disposal could not detect geologically important major elements properly. For example, light elements like magnesium and sodium could not be detected at all.

Because of the absence of important main element data of sodium and magnesium and unreliable silica content, it impossible to use pXRF analyses in conventional geochemical QAPF- or TAS-classification (Le Maitre 2002: 21–42). Therefore, the investigation of trace elements may yield better results than the study of major elements. In principle, the pXRF-device used in this study is able to analyze magnesium, but it would require rhodium as the anode material in the X-ray tube instead of tantalum/gold used in the device at our disposal. Unfortunately, the tantalum/gold anode also affects the measurements of aluminium and silicon causing questionable results. Phosphorous turned out to be problematic too, since the detection limit (LOD) for phosphorous was so high (500–700 ppm = 0.05–0.07 %) that most analyses remained under the lowest possible limit (Olympus 2011). The detection limits for different elements depend on the type of the instrument, X-ray tube material, the detector, used application, calibration, number of the beams, and beaming time. Therefore it is impossible to inform exact detection limits of the elements for each combination, but the closest limits of detection provided by the pXRF-device used in this study are presented in Table 1 (according to Olympus 2011).

Because of the restrictions of the device and detected contamination on the stones, the available major elements for comparison and plotting in this study were potassium, aluminium, iron, titanium and manganese. Since many trace elements remained under the detection limits, the only usable trace elements were vanadium, nickel, zirconium, tin, antimony, lead and cadmium.

Measurements and analysis

Besides mortar and plaster, the medieval building stones in Aboa Vetus were contaminated

Table 1. The detection limits for some elements when analyzed with the similar kind of an instrument than used in this study.

Olympus Delta Premium, 2-Beam, Mining plus, Ta/Au-tube, SDD-detector			
Element	Limit of detection	**Element**	Limit of detection
Mg	Not available	**Fe**	5 ppm
Al	max. 4.0 %	**Ni**	10–20 ppm
Si	max. 0.75 %	**Cu**	5–7 ppm
P	500–700 ppm	**Zn**	3–5 ppm
S	100–250 ppm	**As**	1–3 ppm
K	30–50 ppm	**Zr**	1 ppm
Ca	20–30 ppm	**Ag**	6–8 ppm
Ti	7–15 ppm	**Cd**	6–8 ppm
Cr	5–10 ppm	**Sn**	11–15 ppm
V	7–15 ppm	**Sb**	12–15 ppm
Mn	3–5 ppm	**Pb**	2–4 ppm

by rust, metals and paint which inflect the element content of calcium, iron, manganese, copper, zinc, tin, lead, sodium and titanium. The possible contamination of building stones was evaluated before they were selected for analysis by comparing the analysis results to results from natural stones. As a consequence, a noticeable enrichment of some elements (especially calcium and iron) was detected in the building stones in Aboa Vetus. Since the contaminated stones were excluded from the study, the number of suitable stones for analysis remained limited in some contexts. Furthermore, clearly roundish loose stones were omitted since they cannot be directly connected with quarrying. There were also practical restrictions related to the analysis of stones in some contexts. For example, only the stones in the outer wall of cellar K94:10 were analyzed because the exhibition objects blocked the access to inner walls at that moment. On the other hand, the cellars K94:12, K94:11 and K94:9 were partly still unexcavated and therefore all stones were not visible. After the evaluation of stones and practical restrictions, the most representative stones were chosen for analysis

Table 2. The table presents the number of stone types in each cellar analyzed in this study. The locations of the cellars are presented in Figure 2. Number of available stones reveals the total number of suitable stones that could have been analyzed in this study. In average, 35 % of these were analyzed within the frames of this study.

Id	Cellar	Dating	Number of available stones	Number of analyses	% of stones analysed	Stones by type 1	2	3	4	5	6	7	8	9	Number of stone types/cellar
1	K92:6	1600–1650 (lower constructions can be medieval)	59	14	24	-	3	7	1	-	1	-	2	-	5
2	K92:3	1440s	46	14	54	6	3	-	2	-	1	-	-	2	5
3	K92:5	1293–1350 AD / 1440s	55	25	25	11	1	-	-	6	6	1	-	-	5
4	K93:4	1450s	8	4	50	1	1	-	-	-	-	-	-	2	3
5	K93:5	1450s	51	13	16	4	3	-	2	3	-	1	-	-	5
6	K93:3	1390s	23	8	57	1	1	4	2	-	-	-	-	-	4
7	K95:21	1390s	32	13	41	3	2	7	-	-	-	1	-	-	4
8	K94:7	1440s	63	9	14	1	1	6	-	1	-	-	-	-	4
9	K94:12	15th and 16th c.	38	26	66	7	6	3	8	1	-	-	1	-	6
10	K94:11	15th and 16th c.	33	25	79	12	3	1	3	3	-	-	3	-	6
11	K94:9	c. 1404–1410	20	7	35	-	4	-	-	-	-	3	-	-	2
12	K94:10	c. 1404–1410	35	5	14	-	3	-	-	-	1	1	-	-	3
		Total	463	163	35	46	31	28	18	14	9	7	6	4	52

so that at least one example of different stone types from each cellar was selected. All in all, the number of analyzed stones per cellar varied from eight to 63, which accounts for 14–75 % of all stones used in different cellars (Table 2).

The selected stones were analyzed from two points, which were washed with water and nylon brush. Thereafter, the measurements were taken from the cleaned and dry surface. Both points were measured/counted for 60 seconds per beam, two minutes in total. The average of the measurements was calculated by the pXRF-device, by the standard procedure set by the manufacturer (Olympus 2012: 115–24). The area of detection and analysing in the pXRF was large, 10 mm in diameter, which is more than the size of any single mineral grain in the analyzed stones.

In total, about 260 building stones were examined, documented and analyzed in Aboa Vetus. Forty analyses were excluded because the dating of the context was not confirmed medieval. Furthermore, fifteen analyses were dropped out from the final plotting since there were not equivalent stones for comparison (including the only amphibolite sample). Finally, after discarding the analyses of stones with possible contamination, 163 analyses from twelve cellars remained for plotting and comparison (Figure 2, Table 2).

Local bedrock outcrops were prospected by separating the bedrock outcrop shapefile from the Topographic Database of Finland and from the Terrain map in Turku map service. Bedrock outcrop polygon figures were overlaid with the pre-Quaternary geological map of Finland (Lindberg et al. 1994) and the selection of the outcrops for analysis was done by choosing as diverse rock types as possible. However, the analyzed outcrops do not represent all bedrock types in Turku, but rather the ones that were most accessible and therefore most likely suitable for quarrying in the Middle Ages.

The locations of the sampled and/or analyzed outcrops were marked as waypoints with Garmin Montana 680 GPS (Figure 3). All in all, 88 specimens from the outcrops were collected, photographed, examined, and analyzed. In addition, 16 analyses were made straight from the bedrock outcrop. Consequently, the number of bedrock analyses was 104 in total, but after excluding the analyses of rock types that were

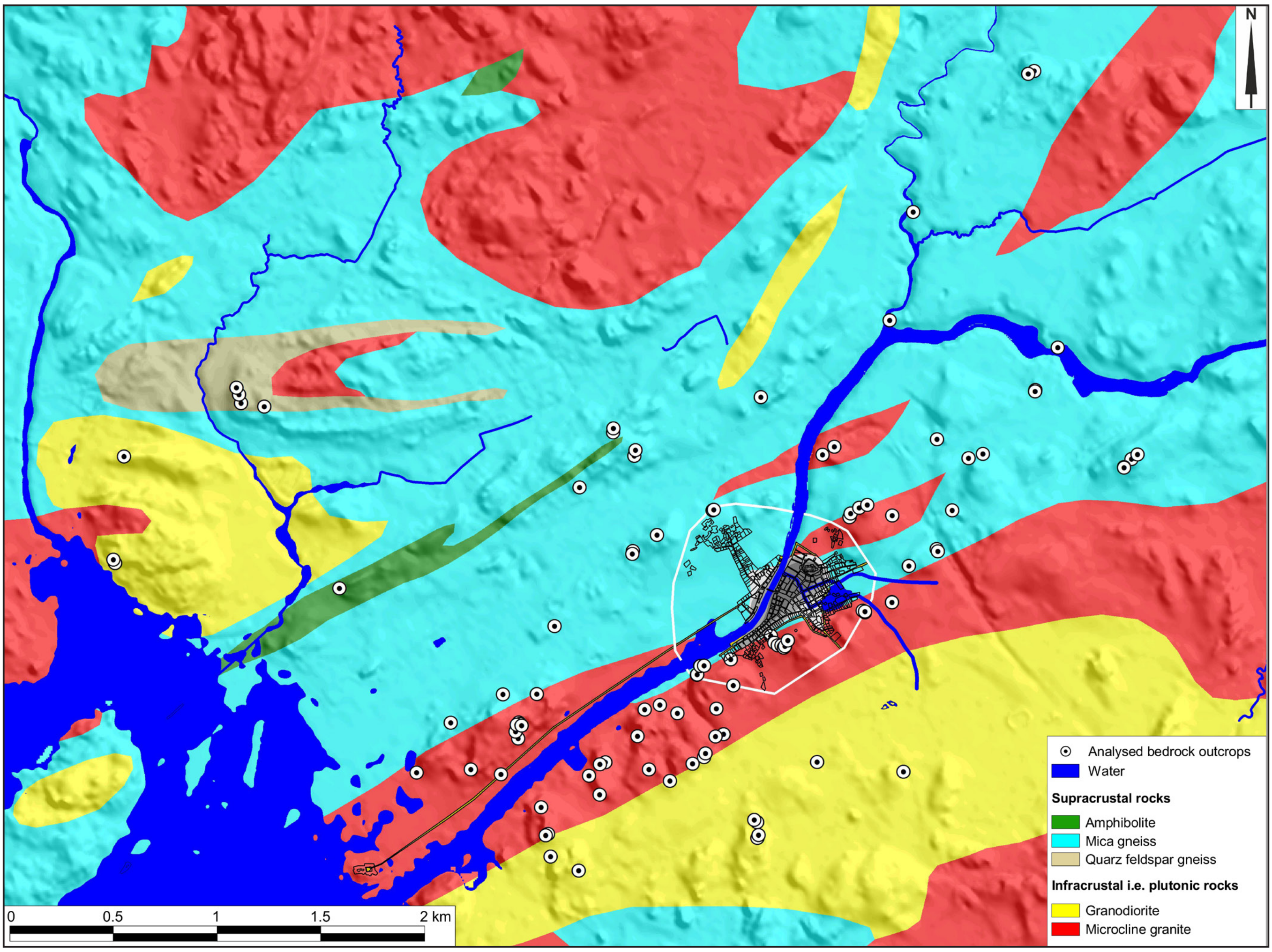

Figure 3. The map presents all analyzed bedrock outcrops. From 104 analyzed outcrops 89 were selected for comparison. The map is modified from the Geological map of Finland, pre-quaternary rocks 1:100 000 of Geological Survey of Finland. (Lindberg et al. 1994.) The figure contains data from Elevation model 10 m of The National Land Survey of Finland.

not used in the buildings (diorite, amphibolite, yellow coloured granite), 89 analyses were left for final geochemical plotting and comparison.

After some experimenting and consideration of element restrictions, plots K-Fe-Al, Zr-Pb-V, Al-Ti, K-Al, K-Fe, and K-Ti were selected for comparison. In practise, K-Fe-Al -plot was the only possible ternary major element plot and therefore all museum and outcrop analyses are plotted in K-Fe-Al-ternary diagrams (Figure 4). Zr-Pb-V-ternary plot gave the largest variation for the most abundant trace elements. Aluminium and titanium are regarded as stabile elements in stones and their ratio reflects the original composition of stones. Therefore, Al-Ti-plot was also used. K-Al, K-Fe, and K-Ti -plots were used for cross checking the other plots used in this study. Analyses were plotted a cellar by cellar and stone type by stone type. Major elements and trace elements were compared separately and data pre-processing was done with MS Excel. The conclusions of the provenances of dimension stones used in Aboa Vetus are based on the comprehensive examination and comparison of all analyses and evidence. Therefore the visual observation of geochemical plots is only one factor in the process of interpretation.

All analyses and geochemical data are presented in detail (including GPS coordinates of all

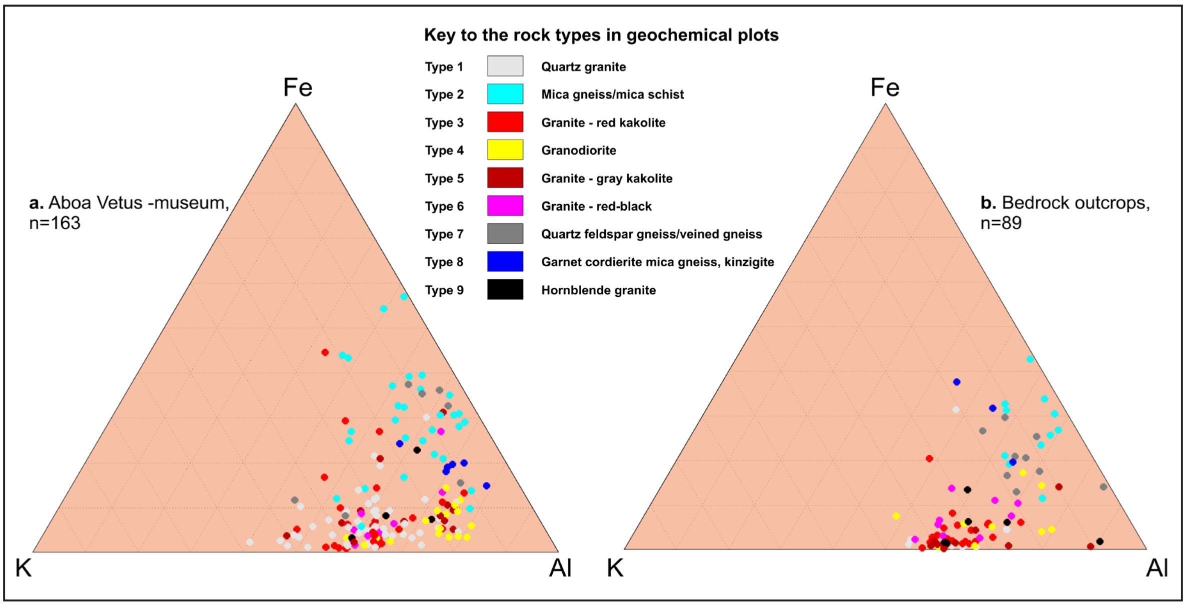

Figure 4. K-Fe-Al-ternary plots of a) all analyses made in Aboa Vetus and b) all outcrop analyses.

analyzed outcrops and location of analyzed building stones in Aboa Vetus) in the MSc thesis of Kinnunen (2018), which was prepared in tandem with this paper and repeats the information and results presented in this article. Hence, geochemical analyses and plotting made in this study can be reconstructed on the basis of available information, but mesoscopic geological comparison is based on personal inspection by Kinnunen with expertise in bedrock geology.

Classification of stones

In this study, geological mesoscopic classification is based on mineralogy on mineralogy, migmatization, colour, grain size and possible metamorphic structures of the stones. The stones analyzed were classified into nine different types according to geological nomination, structure, and appearance (Table 3, Figure 5). In Turku, the most common bedrock is microcline granite i.e. kakolite. In this research, kakolite granite was divided according to colour and appearance (i.e. visible mineralogy) to the following five types: quartz granite (type 1), red granite (type 3), gray granite (type 5), red–black granite (type 6) and special hornblende granite (type 9). The differences in their appearance are caused by variations of mineralogy.

Stone types in the Turku region are presented in the bedrock map in Figure 3 where *Microcline granite* includes stone types 1, 3, 5, 6 and 9 classified in this study. *Mica gneiss* includes both type 2 (mica gneiss) and type 8 (garnet cordierite mica gneiss/kinzigite) which is also common in interbeds in granites. *Amphibolite* has similar sedimentary origin than mica gneiss, but in more mafic sediment beds they metamorphosed to amphibolites and not to mica gneisses. *Granodiorite* contains type 4 (granodiorite) and *quartz feldspar gneiss* is like type 7 (quartz feldspar gneiss/veined gneiss), which is also commonly found in the migmatitic parts of granites.

Besides the classified nine stone types, two limestones were discovered in Aboa Vetus. The limestones are fine grained and homogenous with light greenish grey colour. There are no visible fossils or crawling tracks on the weathered surfaces. The limestones were analyzed but the

Table 3. The table presents the classified stone types in this study according to their representativeness in Aboa Vetus so that the most common one is presented first.

Type 1	**Quartz granite**	
	Main minerals	potassium feldspar and quartz (50:50)
	Appearance	salmon red, transparent glassy quartz
	Structure	coarse grained and homogenous
	Porphyroblasts	none
Type 2	**Mica gneiss/mica schist**	
	Main minerals	quartz, plagioclase and biotite
	Appearance	nearly black
	Structure	fine grained, homogenous and foliated, sometimes schistose
	Porphyroblasts	none
Type 3	**Granite/red kakolite**	
	Main minerals	quartz, plagioclase, potassium feldspar
	Appearance	red
	Structure	medium grained and homogenous
	Porphyroblasts	cordierite ± garnet
Type 4	**Granodiorite**	
	Main minerals	quartz, plagioclase, potassium feldspar, biotite and hornblende
	Appearance	light grey to reddish grey, dark mineral grains
	Structure	mainly medium grained and often clearly foliated
	Porphyroblasts	none
Type 5	**Granite/grey kakolite**	
	Main minerals	quartz, plagioclase, potassium feldspar
	Appearance	bone grey
	Structure	homogenous, medium- to coarse grained
	Porphyroblasts	cordierite ± garnet
Type 6	**Granite/red-black**	
	Main minerals	quartz, plagioclase, potassium feldspar and biotite
	Appearance	red-black
	Structure	medium grained and often clearly schistose
	Porphyroblasts	none
Type 7	**Quartz feldspar gneiss/veined gneiss**	
	Main minerals	quartz, plagioclase, potassium feldspar and biotite
	Appearance	paleosome streaky black and white, neosome granitic and light coloured
	Structure	thoroughly foliated and often folded
	Porphyroblasts	rare
Type 8	**Garnet cordierite mica gneiss/kinzigite**	
	Main minerals	plagioclase, quartz, biotite, potassium feldspar
	Appearance	paleosome black or dark grey, stripes of light coloured granitic neosome parallel to foliation
	Structure	fine to medium grained
	Porphyroblasts	garnet ± cordierite
Type 9	**Hornblende granite**	
	Main minerals	quartz, plagioclase, potassium feldspar, hornblende
	Appearance	salmon red–grey spotted by small black hornblende grains
	Structure	medium grained and homogenous
	Porphyroblasts	garnet ± cordierite

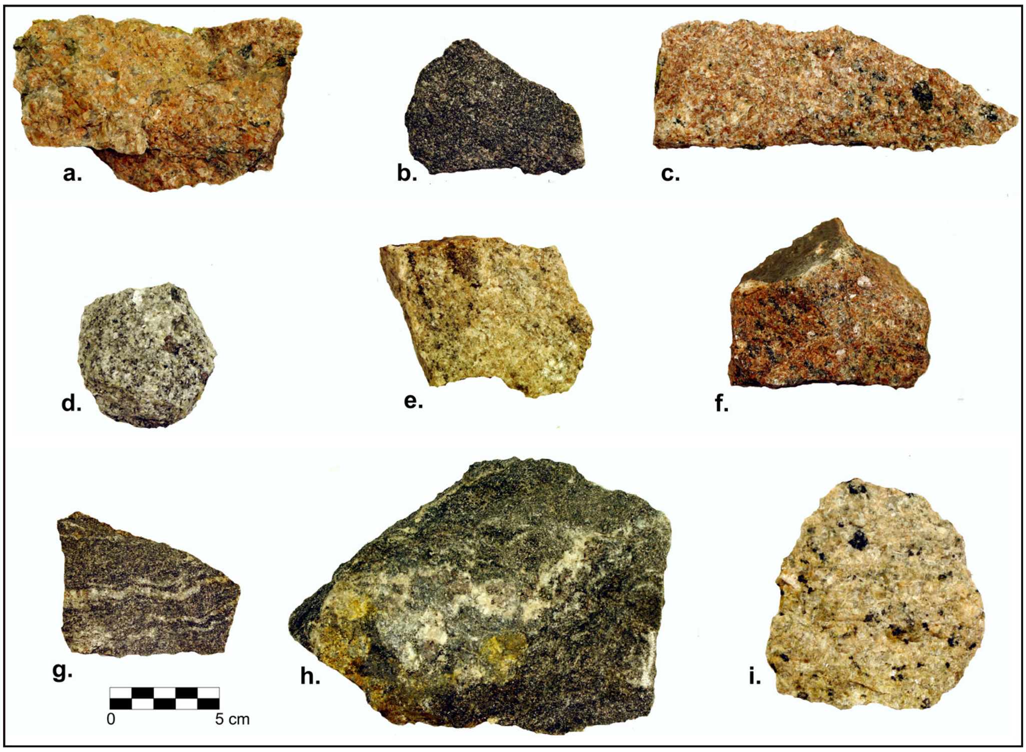

Figure 5. The most common stone types from Aboa Vetus and examined outcrops with coordinates in ETRS89-TM35FIN-projection (EPSG: 3067).
a) Type 1: quartz granite (sample 2016-1-38, Suikkila. N: 6712 322, E: 237 072),
b) Type 2: mica gneiss (sample 2016-2-9, Tuureporinkatu. N: 6711 509, E: 239 807),
c) Type 3: granite – red kakolite (sample 2016-1-23, Amiraalistonkatu. N: 6709 995, E: 238 213)
d) Type 4: granodiorite (sample 2016-2-4, Vesimiehenkatu. N: 6711 420, E-241 290),
e) Type 5: granite – grey kakolite (sample 2016-2-2, Halistenkoski. N: 6712 387, E: 242 006)
f) Type 6: granite – red-black (sample 2016-1-27, Mikaelinpuisto. N: 6710 853, E: 238 786),
g) Type 7: quartz feldspar gneiss/veined gneiss (sample 2016-1-21, Kalastajankatu. N: 6709 997, E: 237 877),
h) Type 8: garnet cordierite mica gneiss/kinzigite (sample 2015-20, Yliopistonmäki. N: 6711 471, E: 240 717),
i) Type 9: hornblende granite (sample 2015-17, Tuomaansilta. N: 6711 858, E: 240 584).
Photo: Jussi Kinnunen

analyses are not included in the geochemical plots because the nearest comparable limestone outcrops are in the bottom of Sea of Bothnia and on a few islands in the archipelago. In Turku region, Fennoscandian Cambrian limestones are commonly found on rocky beaches as loose stones. Imported limestones from Gotland and Estonia are younger, Ordovician to Silurian, and they usually contain detectable fossils (Magnusson et al. 1963: 276–83; Perens & Kala 2007: 16–7).

Stone types and the provenance of building materials

The following descriptions of the cellars included in this study provide information on stone types used in each cellar and an interpretation of the provenance of the building stones. If there is more than one place of provenance for a certain stone type, the most probable one is mentioned first. Exact information of the location of all analyzed stones can be found in the MA dissertation of Kinnunen (Kinnunen 2018: appendices 2 and 3) but in this article each cellar is presented with one photo only.

Cellar K92:6 is located in the entrance hall of Aboa Vetus & Ars Nova museum (Figures 2 and 6). The size of the cellar is circa 15 m². It was built on the remains of an older cellar and represents a slightly younger building phase than the adjacent cellar from the Middle Ages (see below K92:3). Judging from the bonding of the bricks in the upper parts of the southwest wall, the cellar was built after the Middle Ages. Furthermore, the dating of some of the bricks to the first part of the seventeeth century gives support to the time of construction suggested by the bonding. However, the lower parts of the cellar made of stones, as well as the stone floor, may originally belong to the antecedent cellar (Uotila 1995: 2–8; Sartes & Lehtonen 2007: 42–3, 198). Many stones used in the walls are covered with plaster and therefore were not suitable for pXRF analysis. All in all, fourteen stones were analyzed from the walls (Kinnunen 2018: Appendices 2, i–ii; 3, Figure 1) and they represent five different stone types originating from the eastern side of Aura River (Table 3 and Figure 7).

Cellar K92:3 is also located in the entrance hall of the museum (Figures 3 and 8). According to dendrochronological analysis, the cellar has been dated to the late 1440s. The inner walls of the cellar are made of stones, apart from the entrance which is made of bricks and leads to the adjacent staircase (K92:5). The outside and

Figure 6. Cellar K92:6 in the entrance hall of Aboa Vetus & Ars Nova. The upper part of the walls and the barrel vault ceiling was made of bricks. The floor is paved with cobblestones, which are mainly rounded loose stones with the diameter of about 10–20 cm. Photo: Markus Kivistö.

upper parts of the building are made of bricks as well, but the floor of the cellar is made of stones (Uotila 1995: 6–7; 2003: 130; Sartes & Lehtonen 2007: 40). The size of the cellar is about 27.5 m^2, but about two thirds of the southern part of the cellar is not accessible because of the walking bridge made above the cellar. In this study, fourteen stones were analyzed from three different walls of the northern part of the cellar (Kinnunen 2018: Appendices 2, iv–v; 3, Figure 2) and they represent five different stone types originating most likely from the eastern side of Aura River (Table 3, Figure 9).

Cellar K92:5 is a narrow staircase leading to the abovementioned cellar K92:3 in the entrance hall of the museum (Figures 2 and 10). The size of the staircase is 5.5 m x 1.2 m. The lower part of the staircase, as well as the stairs with seven steps leading to the cellar K92:3, are made of stones, but bricks have been used in the walls, too (Sartes & Lehtonen 2007: 40–2). Only one dendrochronological sample from the foundations of the staircase has been analyzed and it has given a much older dating to the staircase (1293–1350 AD) than to the adjacent cellar K92:3 (Uotila 2003: 130; Zetterberg 2003: 390; Sartes & Lehtonen 2007: Appendix 7, 1). However, it is very likely that the staircase and the cellar were built at the same time in the 1440s, since they both belong to the same building. In this study, 25 stones from all the walls of the staircase were analyzed (Kinnunen 2018: Appendices 2, ii–iv; 3, Figure 3) and they represent five different stone types, which originate most probably from the hills on the eastern side of Aura River (Figure 11, Table 3).

Cellar K93:4 locates inside Aboa Vetus and was first excavated already in the 1920s (Figures 2

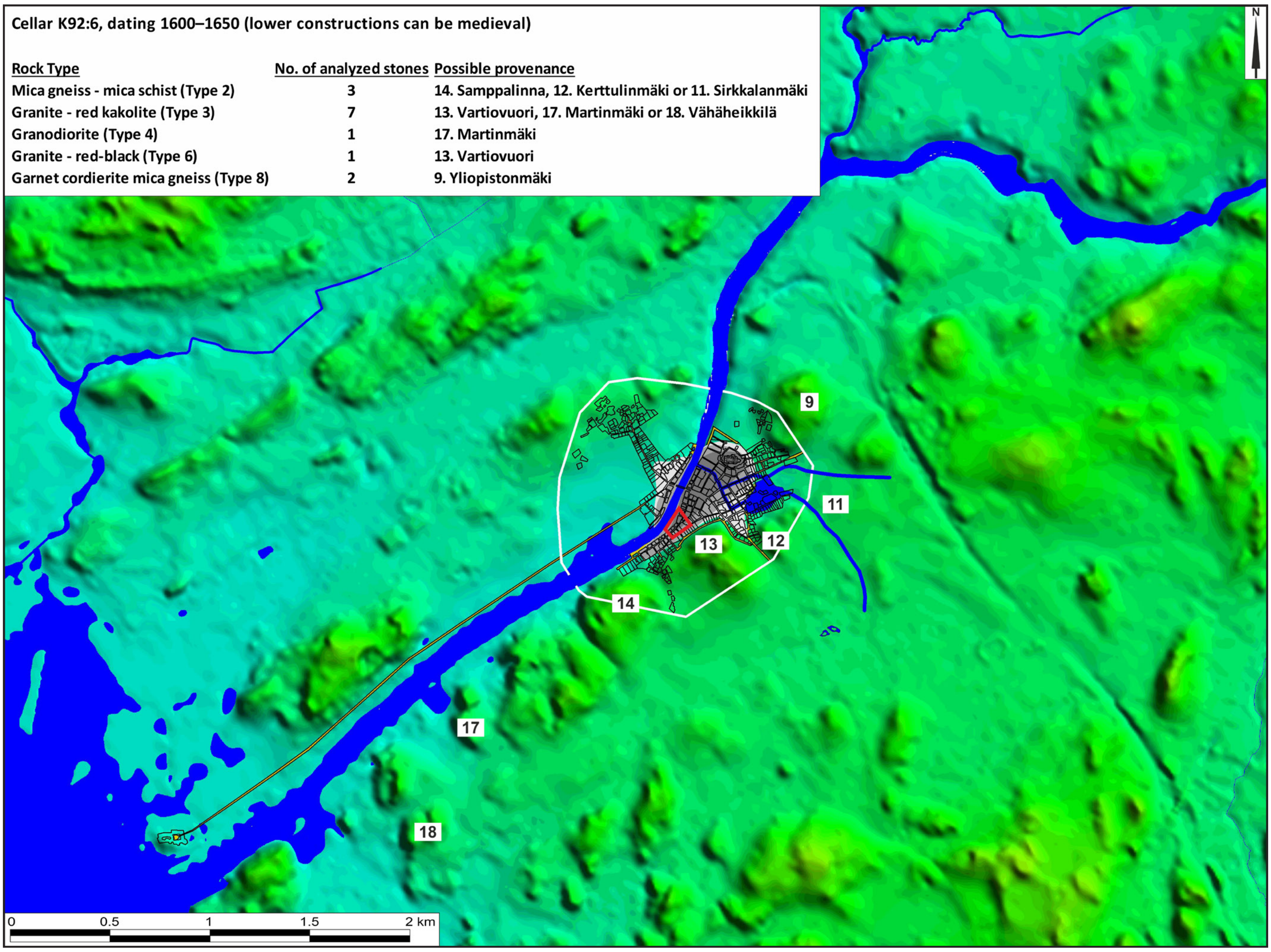

Figure 7. The possible provenance of the dimension stones used in cellar K92:6. The dominant stone type is red granite and all stones have been quarried from the eastern side of the river. The figure contains data from the Elevation model 10 m of National Land Survey of Finland.

Figure 8. Six stones were analyzed from the northern wall of the cellar K92:3. The big block at the bottom of wall is the only red-black granite (type 6) among the analyzed stones in this context. The floor is paved with cobblestones (diameter about 10–20 cm), which were not analyzed in this study. Photo: Markus Kivistö.

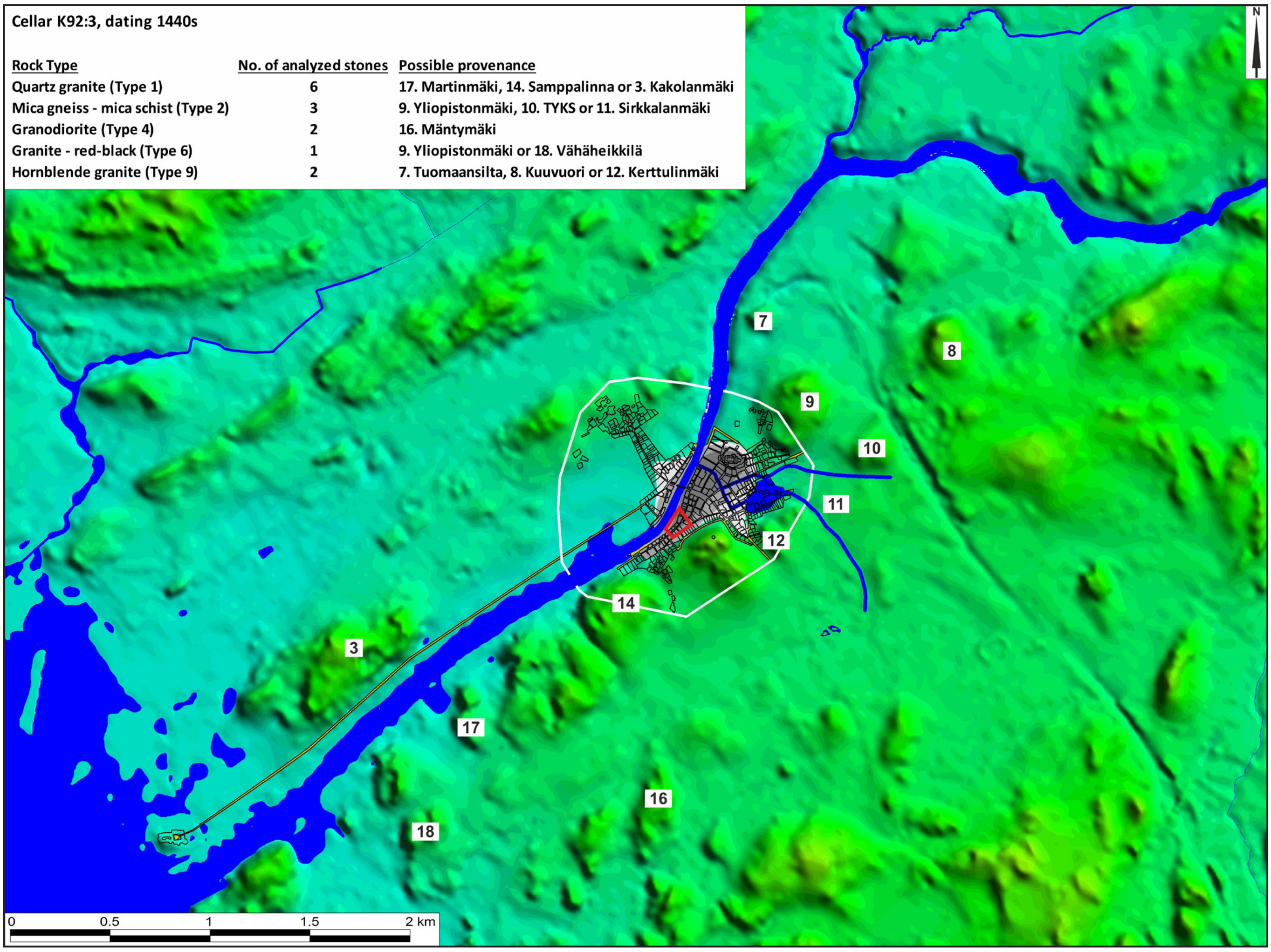

Figure 9. The stones used in cellar K92:3 were quarried from different hills on eastern part of the river. The figure contains data from the Elevation model 10 m of National Land Survey of Finland.

and 12). The size of the cellar is about 18.5 m². According to the dendrochronological dates, the cellar was built in the 1450s as an extension to the older building (Uotila 2007, 22, 25; 2009: 44). The cellar was used until the early 20th century. At the end of the 19th century, it was probably used as a part of a bathing house built in this area in 1874. Thereafter, the building was used as a cigarette factory until the 1920s when it was demolished and the cellars underneath were abandoned. In the course of the centuries the cellar has been renovated and reconstructed. For example, the floor was covered with concrete and the walls were plastered with cement mortar that is still covering major parts of the walls (Uotila 1995: 35–7; Sartes & Lehtonen 2007: 61–3). Apparently, three of the walls were made exclusively of bricks and only the lower part of the northeastern wall was made of stone. In this study, four stones were analyzed from this wall (Kinnunen 2018: Appendices 2, v; 3, Figure 4) and they represent three different stone types (Figure 13 and Table 3).

Cellar K93:5 locates next to cellar K93:4 and both cellars belong to the same building phase of a larger building complex (Figures 2 and 14). Both cellars were probably made during the 1450s. The size of this cellar is only 4.8 m². The lower parts of the walls are made of dimension stones, but the upper part of the walls, as well as the vaulted ceiling, are made of bricks. The walls are partly covered with plaster. In the excavations, no evidence of paving of the floor was found. The cellar was in use until the early 20th century and some renovations were

Figure 10. Cellar K92:5 is actually a narrow staircase leading to the adjacent cellar K92:3. The stairs are made of split stone blocks. Photo: Markus Kivistö.

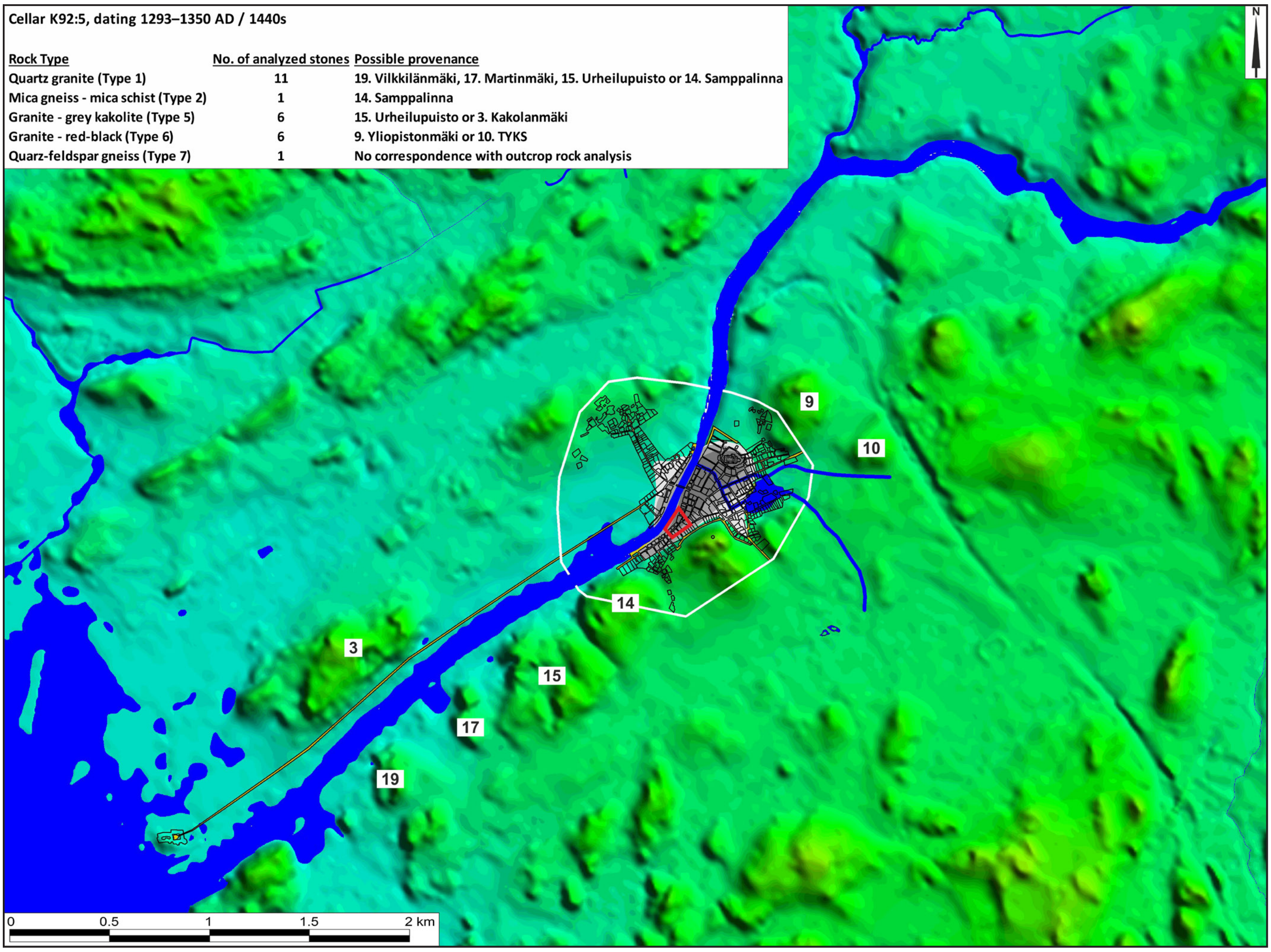

Figure 11. Granites and quartzs are the dominant stone types in cellar K92:5. The stones originate from the hills on the eastern side of Aura River. Gneiss with very low Al and Ti has no parallel in outcrop analyses. The figure contains data from the Elevation model 10 m of National Land Survey of Finland.

Figure 12. All analyzed stones can be found in the northeast corner of the cellar K93:4. The darkest stone on the left above the niche is mica gneiss – mica schist (type 2), the light-grey one next to it is quartz granite (type 2) and the one below it (above the opening) is hornblende granite (type 9). Photo: Markus Kivistö.

made in the course of the centuries here as well. The cellar was found partly demolished and some reconstruction work was carried out in the mid 1990s when the museum was under construction (Uotila 1995: 38–9; Sartes & Lehtonen 2007: 63–4; Uotila 2007: 22; 2009: 44). In this study, thirteen stones of cellar K93:5 were analyzed from three walls where dimension stones were most numerous (Kinnunen 2018: Appendices 2, vi–vii; 3, Figure 5). The stones represent five different stone types as stated in Figure 15 and Table 3.

Cellar K93:3 (Figures 2 and 16) locates next to the abovementioned cellar K93:4 and is closely connected to the adjacent cellar K93:2 (not analyzed in this study). In the late Middle Ages,

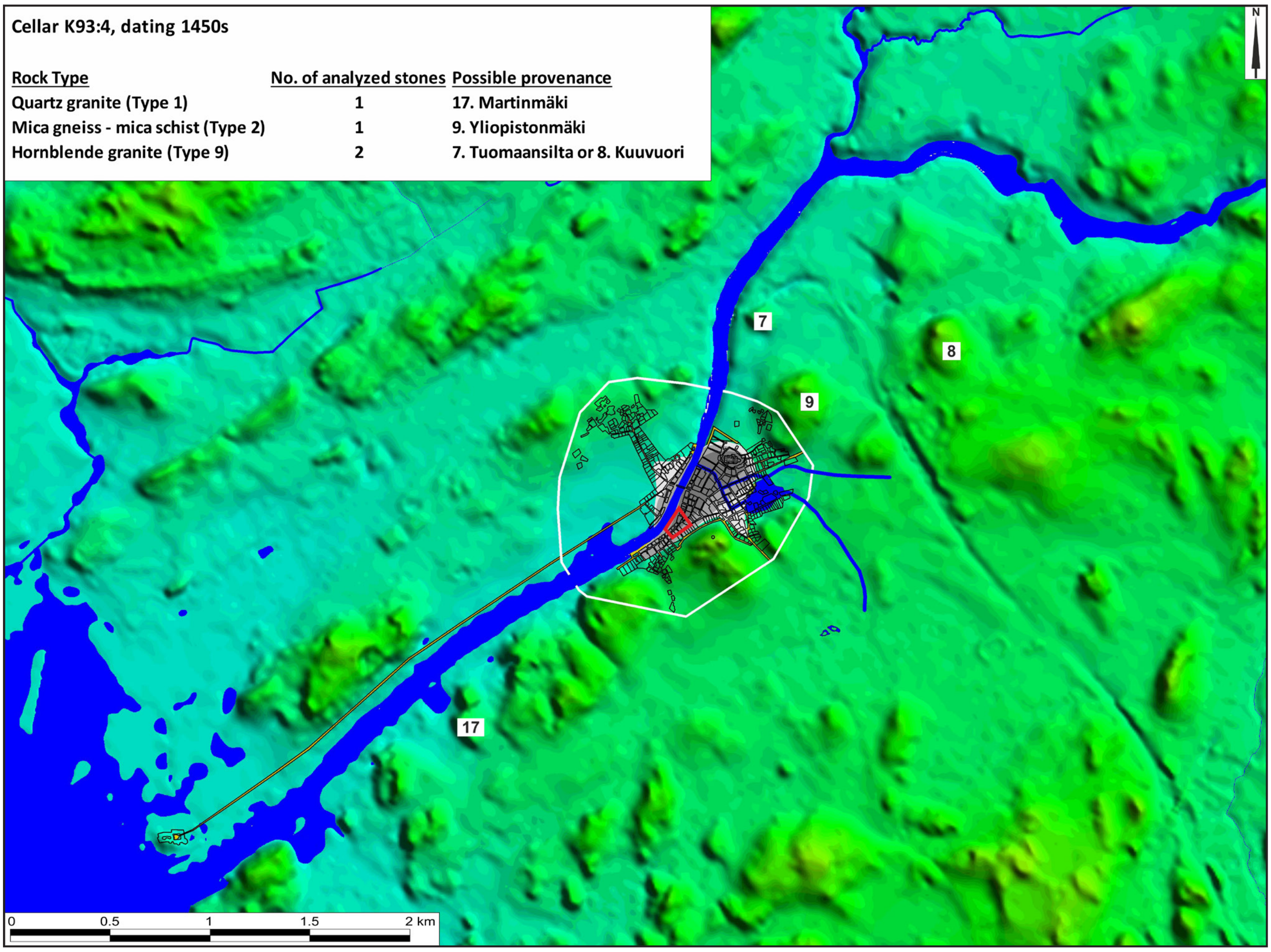

Figure 13. The dimension stones used in cellar K93:4 originate most probably from three hills locating north-east of the medieval town. Hornblende granite (type 9) is quite unique and it is most probably from Tuomaansilta (7) or Kuuvuori (8) where this stone type can be found. The figure contains data from the Elevation model 10 m of National Land Survey of Finland.

Figure 14. Cellar K93:5 was mainly made of bricks but stones were used in the northeastern wall and in the lower parts of the cellar. In this study, eight stones of this wall were analyzed. The dark grey one in the middle on top is the only quartz-feldspar gneiss (type 7) in this cellar. Photo: Markus Kivistö.

all these cellars belonged to the same building complex. This cellar represents the oldest part of the building and has been dated to the 1390s (Uotila 2007: 22; 2009: 44). The size of the cellar is circa 12.3 m² with the maximum height of 2.15 m. The northwestern wall is mainly made of stones, but otherwise the walls are mostly made of bricks so that stones have been used in the corners and in the lower parts the walls. The vaulted ceiling is made of bricks. Also this cellar was in use until the early 20th century as a part of a bathing house. In the course of the centuries, the original floor made of cobblestones was covered with concrete and the walls were covered with plaster. Furthermore, an old entrance was replaced with a new one (Uotila 1995: 30–4; Sartes & Lehtonen 2007: 60–1). Eight stones were analyzed from two walls visible in Figure 16 (Kinnunen 2018: Appendices 2, v–vi; 3, Figure 6). The analyzed stones represent four different stone types (Figure 17 and Table 3).

Cellar K95:21 locates next to the abovementioned cellar K93:5 (Figure 2), but probably the cellars belong to different buildings and represent different construction phases. The size of the cellar is only 7.4 m². The walls of the cellar are mainly made of big dimension stones. Also the vaulted ceiling is made of stones and the floor of the cellar is made of small cobblestones (Figure 18). Compared to the size of the cellar, the doorstone is very big, 1 m x 1 m. The cellar belongs to the building complex that has been dated to the 1390s, but it has a long history reaching until the 19th century (Sartes & Lehtonen 2007: 85–6; 2009: 44). In this study, thirteen stones from the walls and a large step stone were analyzed (Kinnunen 2018: Appendices 2, vii–viii; 3, Figure 7). The stones in this cellar represent four different stone types (Figure 19 and Table 3).

Cellar K94:7 locates in the westernmost corner of Aboa Vetus (Figures 2 and 20). According to dendrochronological analysis, the cellar was constructed in the 1440s. At the end of the 19th century, it was still in use as a part of a bathing house on site. Despite the long use-history including renovations, it is one of the most well preserved cellars in the museum, with a maximum height of approximately four meters. It is also one of the biggest cellars with an area of about 55 m². Stones in the lower parts of the cellar belong possibly to the original construction phase from the Middle Ages. The western wall of the cellar is mainly made of stones, which have been covered with plaster in a later phase. The floor is made of cobblestones and the vaulted ceiling is made of bricks (Sartes & Lehtonen

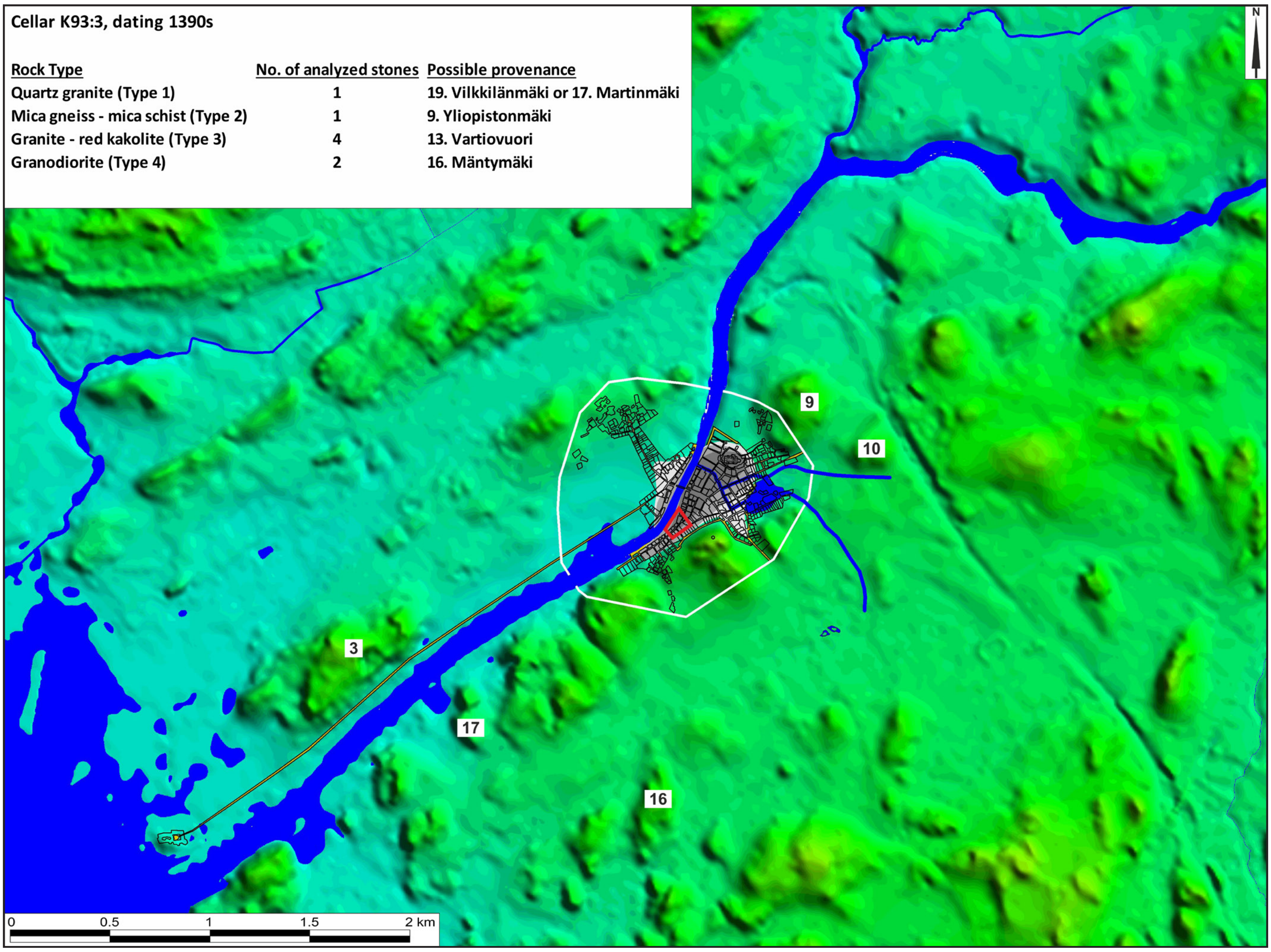

Figure 15. The dimension stones analyzed from the cellar K93:5 originated most probably from four hills outside the medieval town area. The figure contains data from the Elevation model 10 m of National Land Survey of Finland.

Figure 16. The cellar K93:3 was mainly made of bricks, but some stones were used in the northwestern (front) and northeastern (right) walls from where eight stones were analyzed and they represent all four stone types used in this cellar. Photo: Markus Kivistö.

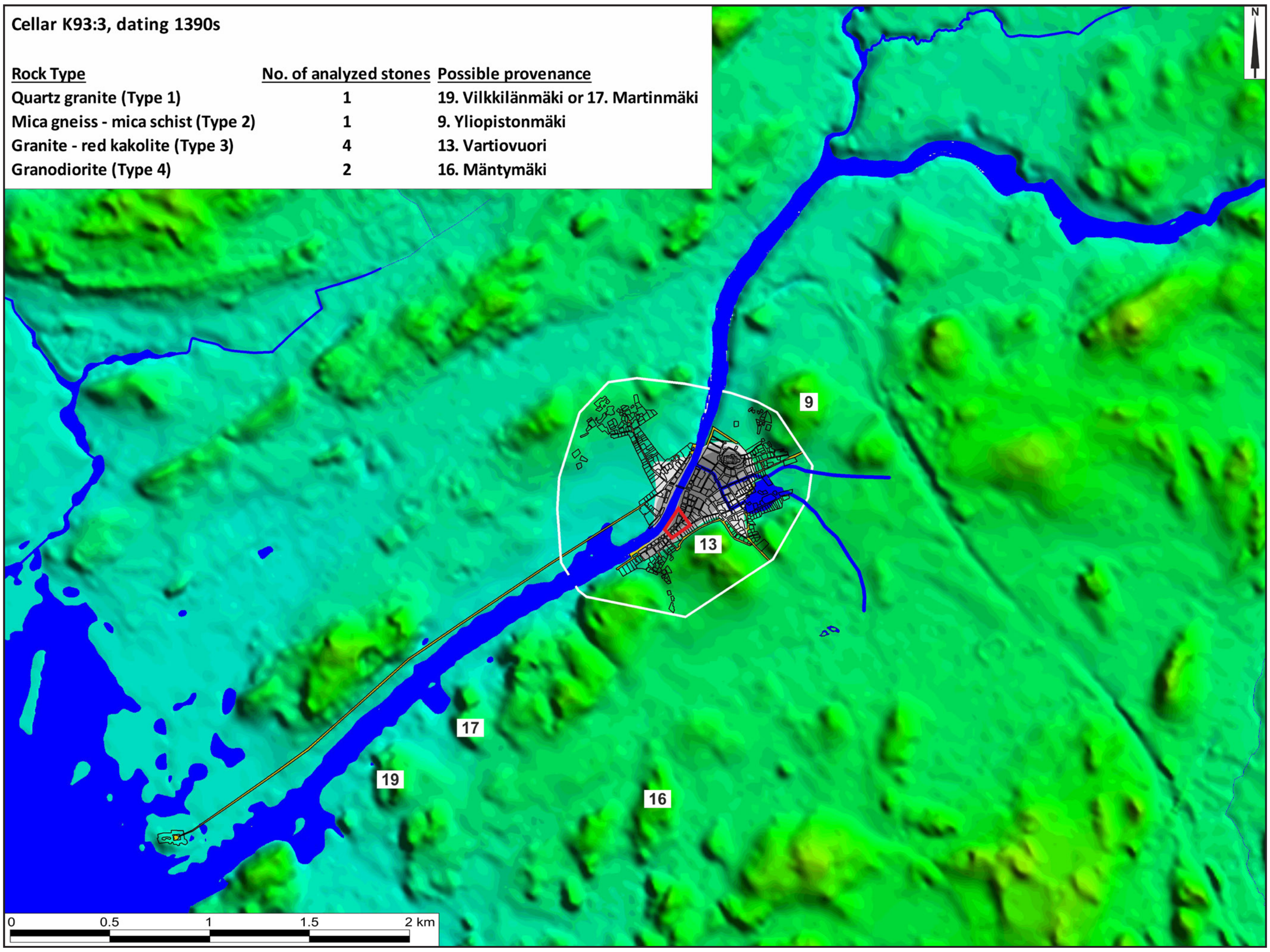

Figure 17. In cellar K93:3 four stone types were used. The dominant stone type is red granite originating from the adjacent Vartiovuori Hill (13). Other stones originated from others hills on the eastern side of Aura River. The figure contains data from the Elevation model 10 m of National Land Survey of Finland.

Figure 18. Cellar K95:21 was mainly made of dimension stones. The analyzed step stone can be seen in front of the back wall. Photo: Markus Kivistö.

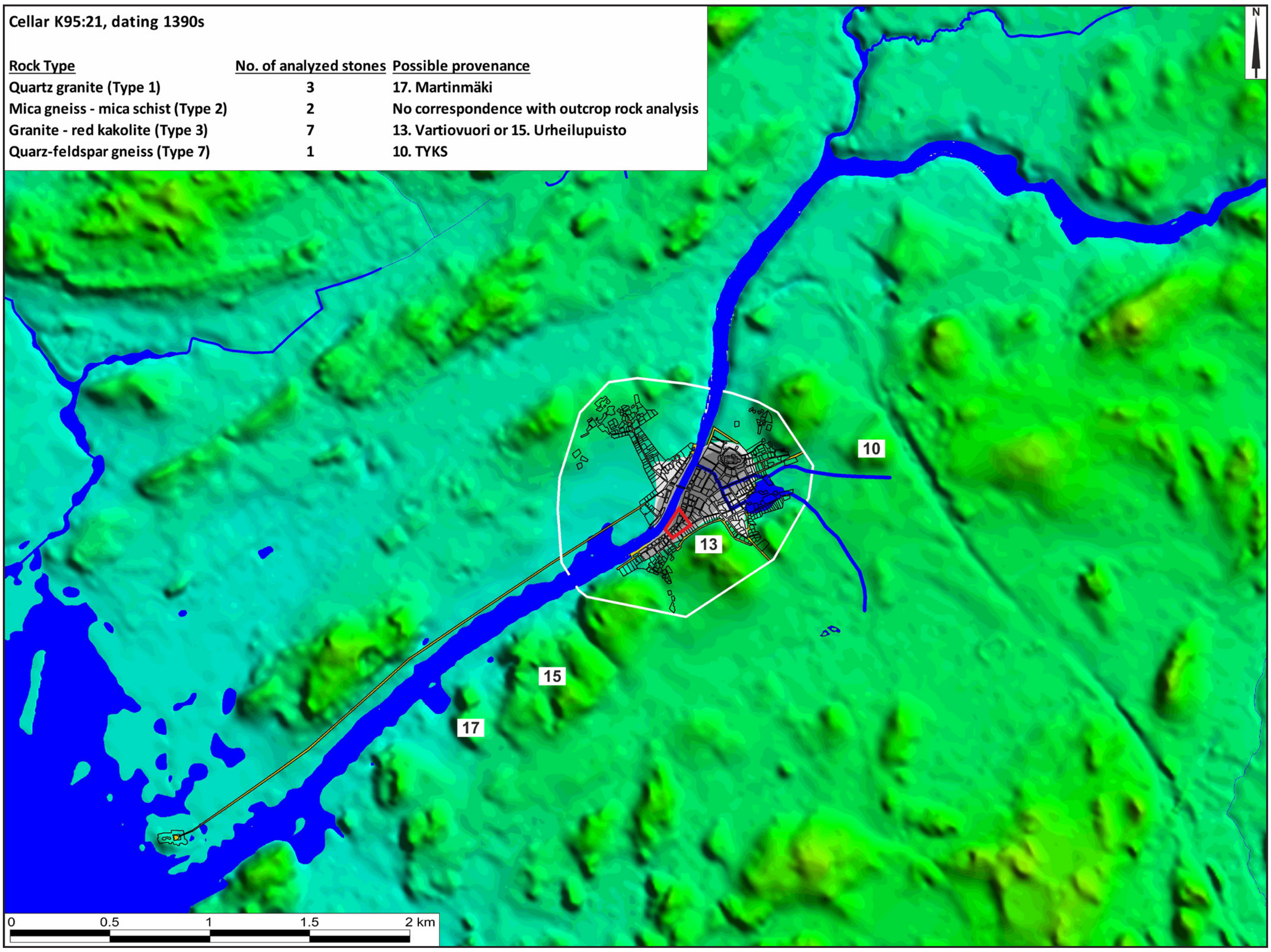

Figure 19. In cellar K95:21, the dominant stone type is red granite originating most probably from the adjacent Vartiovuori Hill (13). The other stones originated from the other hills on the eastern side of Aura River. Analyzed mica gneisses differ slightly from the analyzed outcrops due to the abundant amount of TiO2. However, the possible provenance can be located to the University hospital area (TYKS, 10). The figure contains data from the Elevation model 10 m of National Land Survey of Finland.

2007: 67–71; Uotila 2009: 44). In this study, nine stones in total were analyzed, including stones from all walls (Kinnunen 2018: Appendices 2, viii–ix; 3, Figure 8). The stones represent four different stone types (Figure 21 and Table 3).

Cellar K94:12 belongs to a larger building complex made in the 15th or 16th century (Figure 2). The size of the cellar is about 14.4 m² (Uotila 2009: 4). The walls are mainly made of dimension stones (Figure 22) apart from the brick entrance on the south-east wall leading to the adjacent staircase (K94:11). The floor is made of stones of various sizes, but the vaulted ceiling was made of bricks (Sartes & Lehtonen 2007: 82–3). In this study, 26 stones were analyzed from the walls and from the step stones of the cellar (Kinnunen 2018: Appendices 2, xi–xiii; 3, Figure 9). These stones represent six different stone types (Figure 23 and Table 3). A couple of stones, including a limestone used on the floor, did not have corresponding outcrops, which suggests a practise of using loose stones or possible transportation of single stones.

Cellar K94:11 is a narrow staircase leading to the abovementioned cellar K94:12 (Figures 2 and 24). They both belong to the same building phase and have been dated to the 15th and 16th centuries. The length of the staircase is about 5.5 m and it consists of six stone steps and a narrow doorstone in the upper part of the staircase. The size of the doorstone connecting the cellars K94:11 and K94:12 is 76 cm x 60 cm. The width of the staircase is about 1.5 m. The lower part of the northeast wall is made of large stones (the biggest being 2.2 m x 1.2 m), but the upper parts of the walls are made of bricks. The floor is made of small stones (Sartes & Lehtonen 2007: 80–1). In this study, seventeen stones from three walls and eight stones from the staircase and floor were analyzed, 25 stones in total (Kinnunen 2018: Appendices 2, ix–xi; 3, Figure 10). The stones represent six stone types (Figure 25 and Table 3).

Figure 20. In cellar K94:7, dimension stones were mainly used in the lower parts of the walls. In the photo, you can see the western wall from where four stones were analyzed. All stones are red granite (type 3) quarried from the adjacent Vartiovuori Hill. Photo: Markus Kivistö.

Cellar K94:9 locates next to cellar K94:12 and the staircase K94:11 mentioned above. It belongs to the biggest building in the museum area, to which are included also cellar K94:10 presented below and staircase K94:8 not analyzed in this study (Figures 2 and 26). The size of the building is about 150 m². Cellar K94:9 is the larger of two cellars separated from each other by an inner wall made of bricks. Otherwise, the walls are mainly made of stones

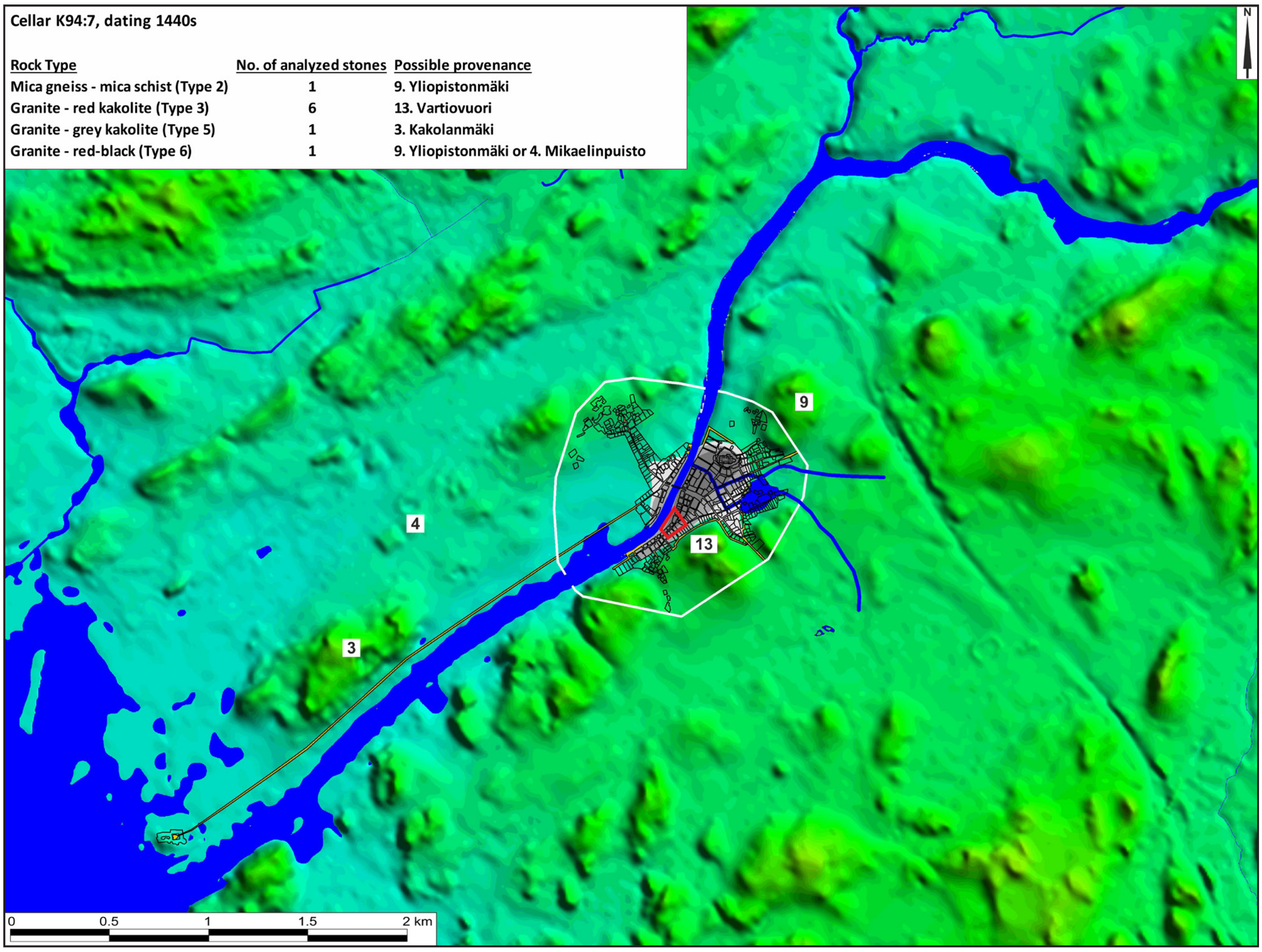

Figure 21. The dominant stone in the cellar K94:7 is red granite which was quarried from adjacent Vartiovuori Hill (13). A few stones originate from other hills around the city. The figure contains data from the Elevation model 10 m of National Land Survey of Finland.

and the floor is mainly made of cobblestones with a few larger stones in between. The size of the cellar (floor area) is about 40 m^2. The building complex has been dated to the early 15th century (ca. 1404–1410 AD) and it was used until the mid 17th century (Uotila 2003: 127; 2007: 22; Sartes & Lehtonen 2007: 74–5, 199–200; Uotila 2009: 44; Lehtonen & Aalto 2012: 6, 19–25; Aalto 2016: 8, 21–5). In this study, seven stones from two walls were analyzed (Kinnunen 2018: Appendices 2, xiii–xiv; 3, Figure 3) and they represent two different stone types (Figure 27 and Table 3).

Cellar K94:10 belongs to the same building complex than the abovementioned cellar K94:9 and the staircase K94:8 leading to this cellar (Figures

Figure 22. Some stones of notable sizes have been used in the south-west wall of cellar K94:12. From this wall nine stones were analyzed and they all can be seen in this picture. Three gray stones framing the niche are gradiorite (type 4), which is the most often used stone type is this cellar. The reddish one on the foot of the wall is quartz granite (type 1) and the big block below the niche is mica gneiss – mica schist (type 6) that are also frequently used in this cellar. Photo: Markus Kivistö.

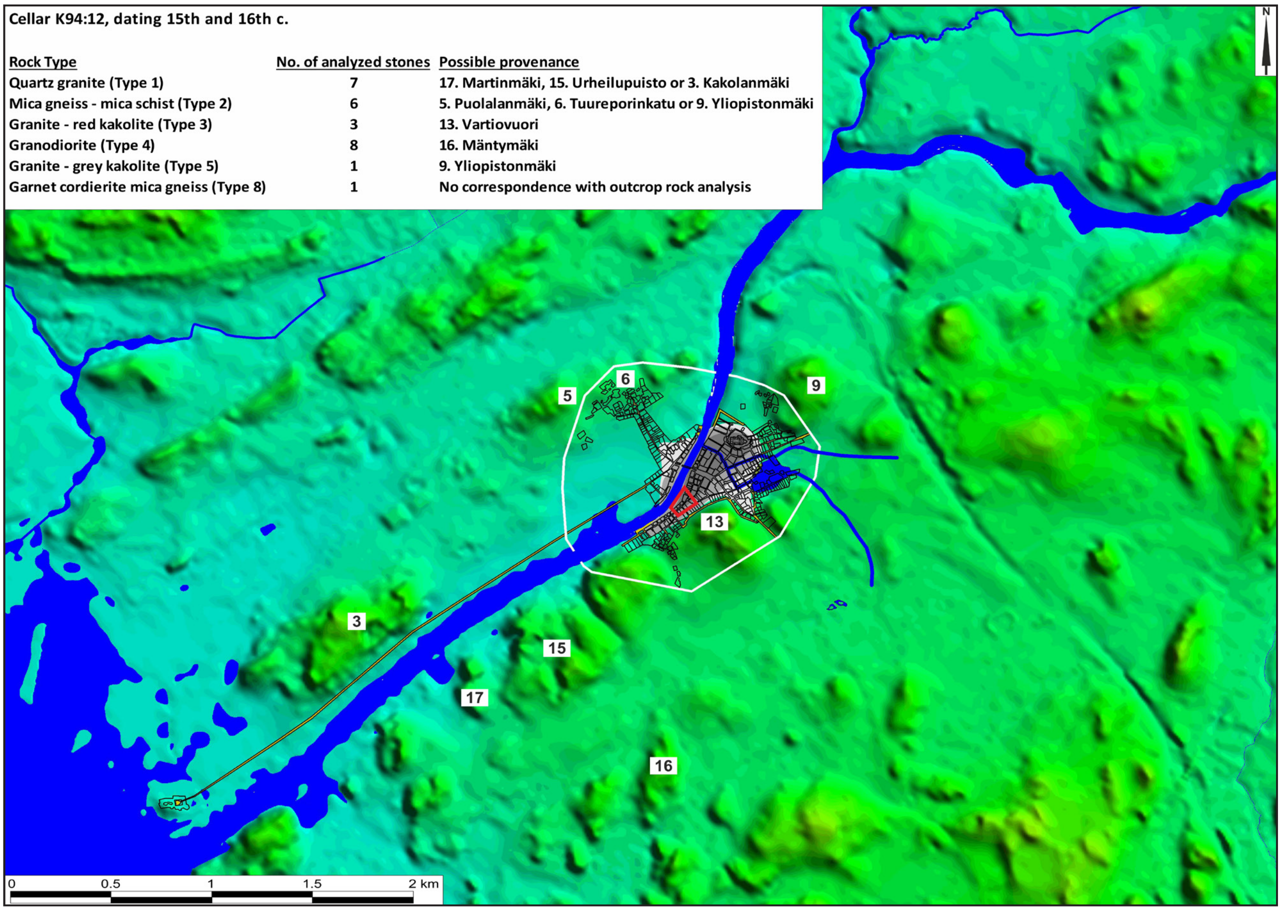

Figure 23. Granodiorite, quartz granite and mica gneiss are the dominant stone types in cellar K94:12. Garnet cordierite mica gneiss did not have correspondence with outcrop analyses, but most probably it originates from Yliopistonmäki Hill like the same stone type used in the adjacent cellar K94:11, too. The stones used in the cellar K94:12 originate most likely from the hills on the eastern side of Aura River. The figure contains data from the Elevation model 10 m of National Land Survey of Finland.

2 and 28). According to dendrochronological analyses, the cellar was built around 1410 AD. The size of the cellar is about 33.8 m². The remaining walls (apart from the inner wall separating the cellars K94:10 and K94:9) are mainly made of dimension stones, but bricks have also been used especially in the southwestern wall and in the entrance leading to the staircase. Also the floor of the cellar is made of stones, as well as the vaulted ceiling, which had later been repaired with bricks and does not exist anymore. Probably, the inner walls of the first floor were also made of dimension stones (Uotila 2003: 127; Sartes & Lehtonen 2007: 75–80; Aalto 2016: 25–7). In this study, five stones were analyzed from the outer wall of the cellar (Figure 28; Kinnunen

Figure 24. The stairs of cellar K94:11 are mainly made of quartz granite (type 1). The stepstone at the entrance leading to cellar K94:12 (on left) is mica gneiss – mica schist (type 2). The big block on the right side of the corridor is garnet cordierite mica gneiss (/kintzigite, type 8) which is is one of the biggest stones (1.2 m x 2.2 m) in the whole museum area. Photo: Markus Kivistö.

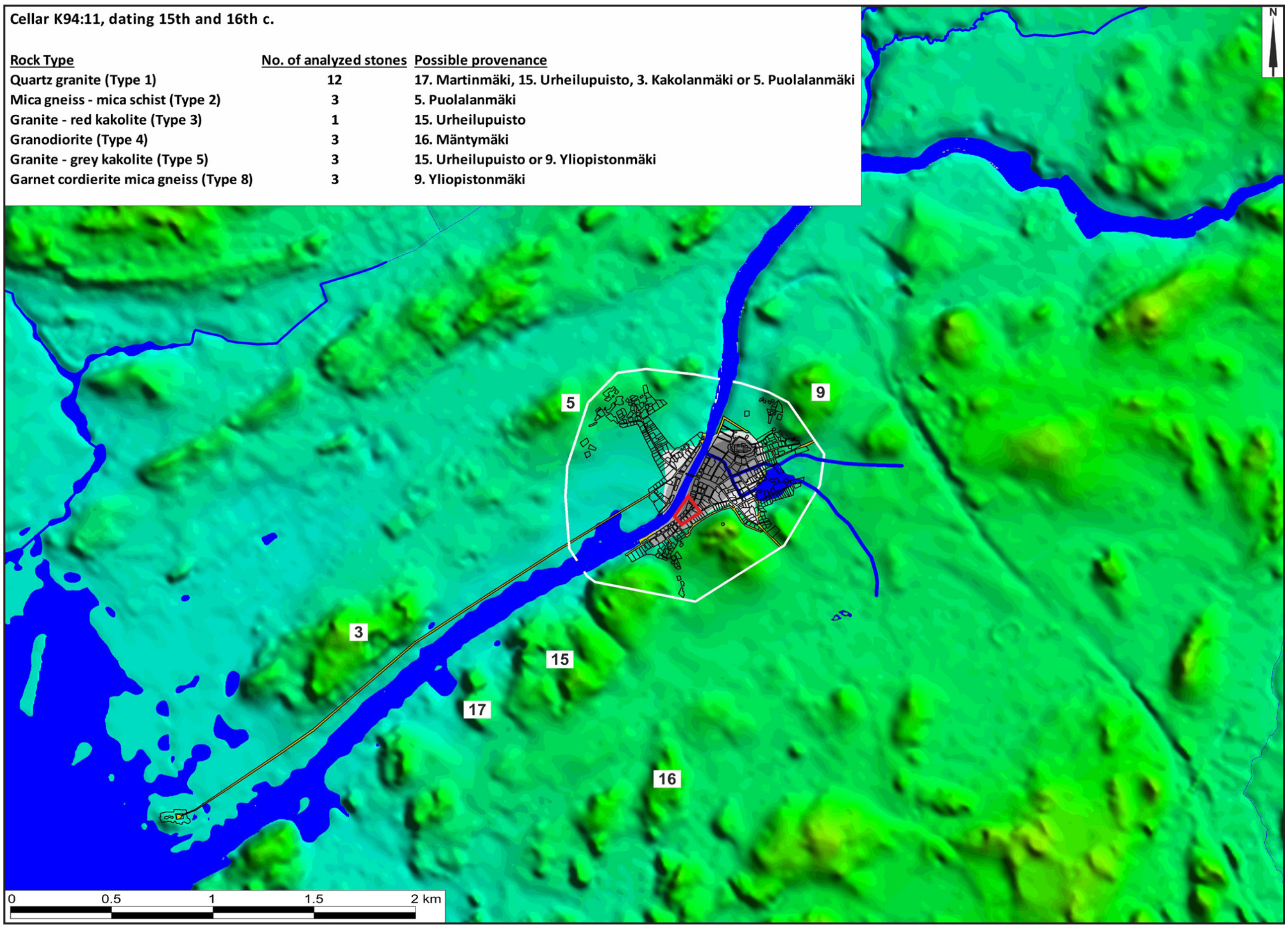

Figure 25. Quartz granite (type 1) is clearly the most dominant stone type in cellar K94:11 used both in the stairs and in the walls. The large garnet cordierite mica gneiss block visible in figure 24 is most probably from Yliopistonmäki Hill. All stones originate most probably from the hills on the eastern side of Aura River. The figure contains data from the Elevation model 10 m of National Land Survey of Finland.

Figure 26. The southwest wall of cellar K94:9 with two arched recesses. The stones visible in the eastern recess on the left are all mica gneiss – mica schist (type 2). ¬At the time of this study, archaeological excavations in this cellar were still going on. Photo: Markus Kivistö.

2018: Appendices 2, xiv; 3, Figure 12), and they represent three different stone types (Table 2 and Figure 29).

Discussion of the results

The analyses demonstrate that in Turku building stones have been quarried from local bedrock since the end of the 14th century. In the studied cellars, kakolite-group granites were used most often (62 % of all analyzed stones) and the most common stone type was quartz granite (28 % of all stones). Mica gneiss / mica schist, kinzigite and quartz-feldspar gneiss together constitute 27 % of all stones analyzed in this study (Table 4). These stones split easily along the foliation and therefore are easier to quarry and work than hard granite. In Turku region, mica gneiss bedrock is located in valleys and depressions usually covered with quaternary deposits and therefore it was unreachable in the Middle Ages. However, mica gneiss interbeds (from one to tens of meters thick) can be found on the hill-

Table 4. The prevalence of different rock types and the use of different stone types can be estimated according to the number of analyses made in this study.

Stone type	Stone name	Number of analyses from Aboa Vetus	Number of analyses from outcrops	Total
1	Quartz granite	46	10	56
2	Mica gneiss	31	11	42
3	Granite – red kakolite	28	20	48
4	Granodiorite	18	10	28
5	Granite – grey kakolite	14	11	25
6	Granite – red-black	9	9	18
7	Quartz feldspar gneiss	7	9	16
8	Kinzigite	6	3	9
9	Hornblende granite	4	6	10
	Analyses in total	163	89	252

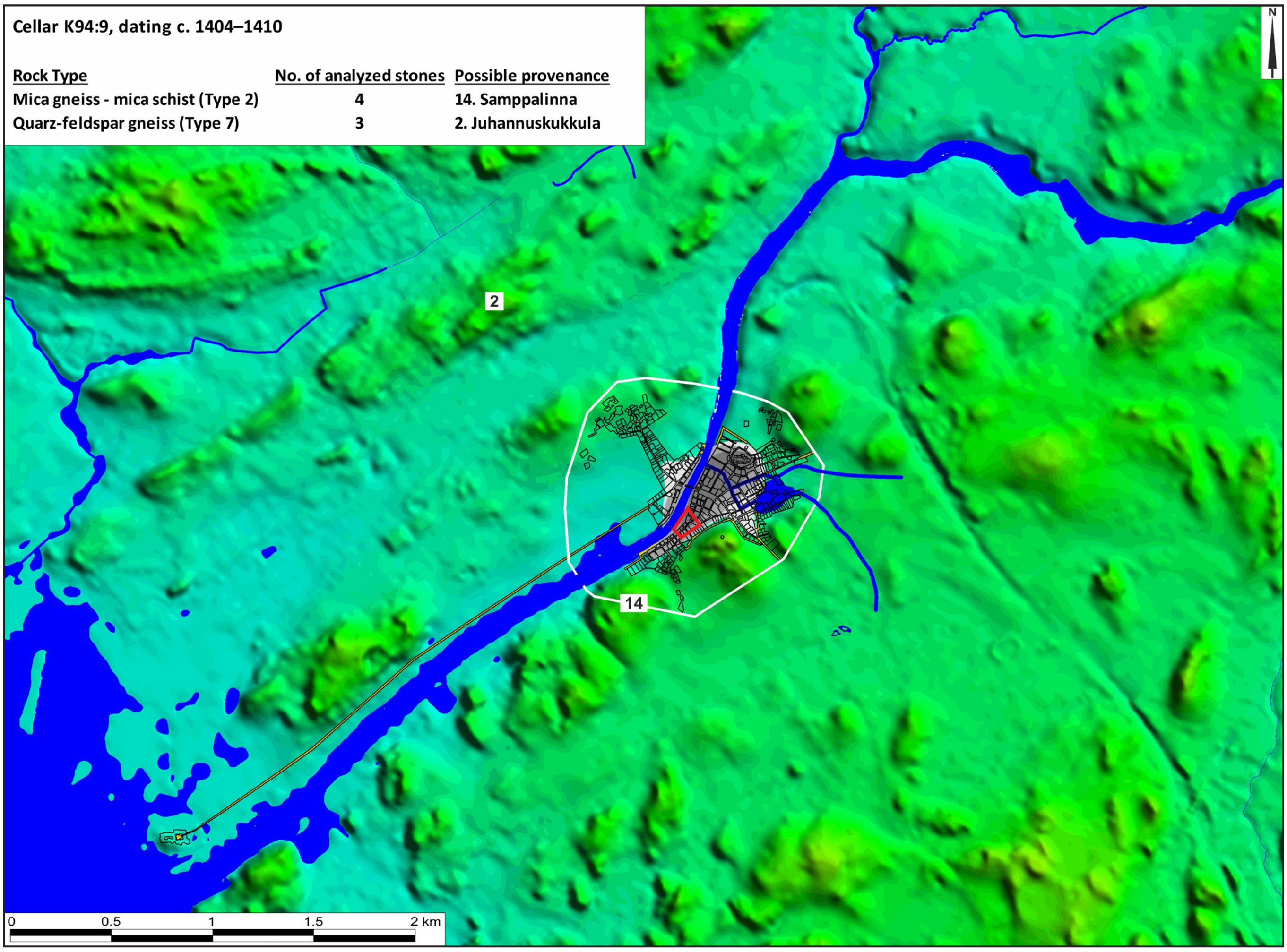

Figure 27. The analyzed stones in cellar K94:9 represent two different stone types. Mica gneisses (type 2) are abundant in vanadine and the similar kind of stone is found from Samppalinna Hill (14). Apparently, all mica gneiss stones originate from the same quarry. Quartz-feldspar gneiss is probably from Juhannuskukkula Hill (2) north of the town. The figure contains data from the Elevation model 10 m of National Land Survey of Finland.

sides between granite layers. Therefore it may have been easy to quarry mica gneiss interbeds together with granite. The remaining 11 % of the analyzed building stones were granodiorite, which is clearly distinguishable from other stones. The closest area with granodiorite deposits is located at a distance of 0.5 km south of medieval Turku. A few single limestones suggest some stones were transported from the Baltic area, but otherwise there is no evidence of long-distance transportation of stone material in the Middle Ages in Turku.

The hills on the eastern side of the Aura River were used for the acquisition of stones throughout the Middle Ages. The town was founded on the eastern side of the river at the beginning of the 14th century and although the urban area expanded on the western side of the river at the end of the 14th century, the heart of the medieval town with most handsome and significant buildings remained on the eastern side. It was not until in the latter part of the 16th century when the role of the western side of the river was transformed and it was inhabited by people with good status and wealth (Nikula 1987: 105–9; Seppänen 2011: 479–80; 2012: 941–6; 2016: 94–6). On the basis of this study, the first evidence of stone material acquisition from the western side of the river can be dated to the end of the Middle Ages, when mica gneiss from Puolalanmäki was used to build cellars K94:11 and K94:12. In

Figure 28. Even the largest stones in the northeast wall of the cellar K94:10 are round shaped suggesting that they can be loose stones (cf. K94:12). Therefore, only five stones from this wall were analyzed. The stones on the left below belong to a well that was not analyzed in this study. Photo: Markus Kivistö.

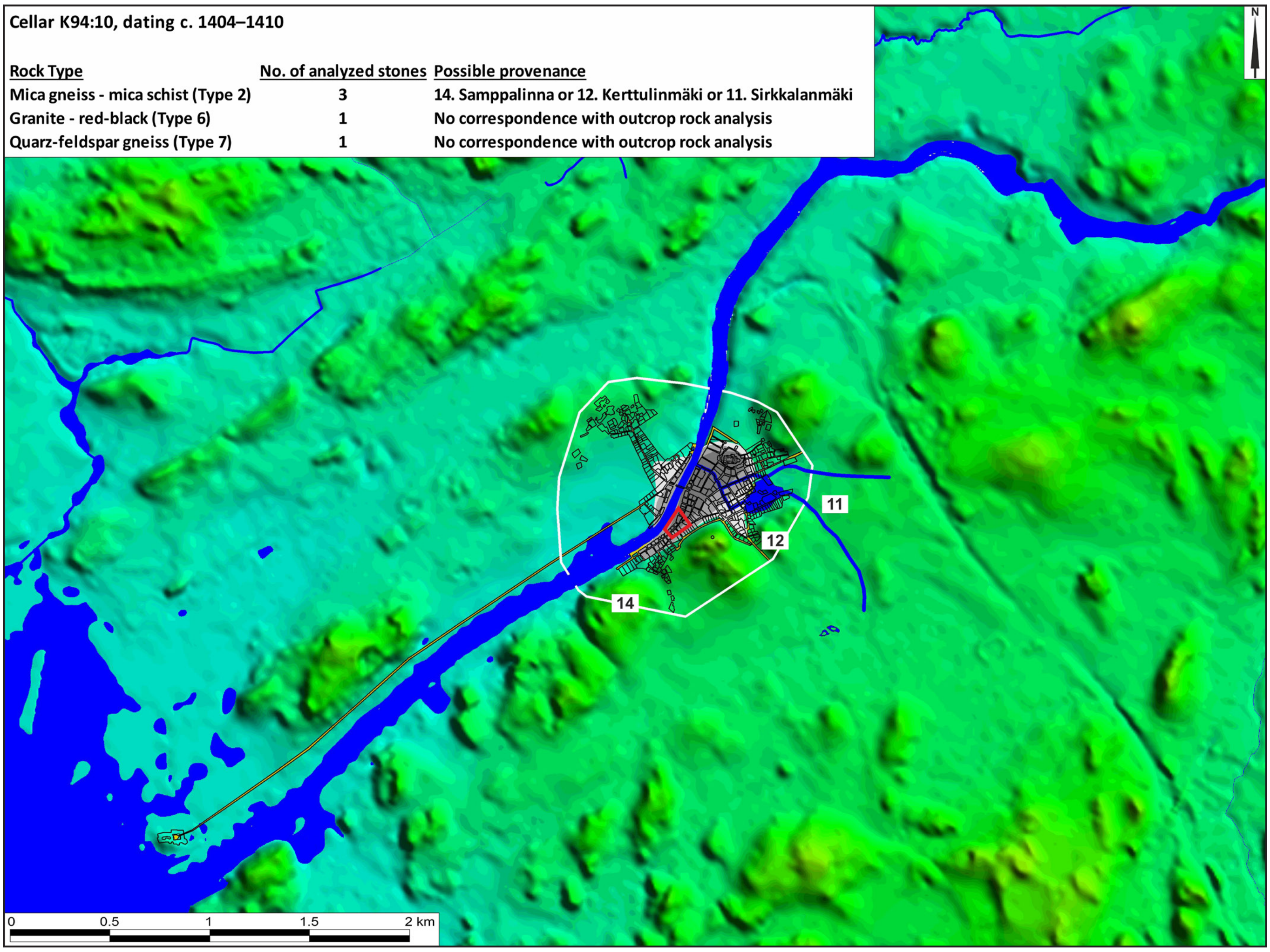

Figure 29. All mica gneiss stones (type 2) used in cellar K94:10 are most probably from Samppalinna Hill (14) locating close to the building site, but the provenance of red-black granite (type 6) and quartz-feldspar gneiss (type 7) cannot be defined. The figure contains data from the Elevation model 10 m of National Land Survey of Finland.

these cellars also granodiorite was used, which indicates that for some reason the stone material in this case was acquired from a more distant location outside the medieval city. The first bridge across the river was constructed in 1414 (REA 349), which facilitated the transportation and traffic across the river. According to this study, no transportation of stones across the river took place prior to the construction of the bridge. However, we need to remember that the utilization of the hills on the western side of the river may prove to have been more active in the late Middle Ages if the masonry buildings excavated on that side are also studied. On the basis of this study, however, we can make the conclusion that in medieval Turku building stones were acquired close by and preferably from the same side of the river (Figure 30).

According to this study, it is possible to divide medieval quarrying areas in Turku into the following five groups (Figure 31):

Urheilupuisto, Samppalinna, Vartiovuori, and Kerttulinmäki have a similar geological setting with red granite as the main bedrock type. Red granite was quarried from Vartiovuori Hill also in later times. Also the softer mica gneiss interbeds are common in this area. According to our study, stones from this area were used throughout the Middle Ages in Turku.

Martinmäki, Vähäheikkilä, Vilkkilänmäki, and Kakolanmäki are mainly labeled as belonging to the kakolite area with coarse kakolite granites (quartz granite, grey granite and red-black granite) as the most common bedrock type. Geochemically it is impossible to distinguish the provenance more precisely, but it is very likely that Kakolanmäki Hill was not quarried on a large scale in the Middle Ages to meet the needs in the town area. However, kakolite from Kakolanmäki Hill could have been quarried for the construction of Turku Castle in the Middle Ages, but this should be investigated with material analysis of the castle.

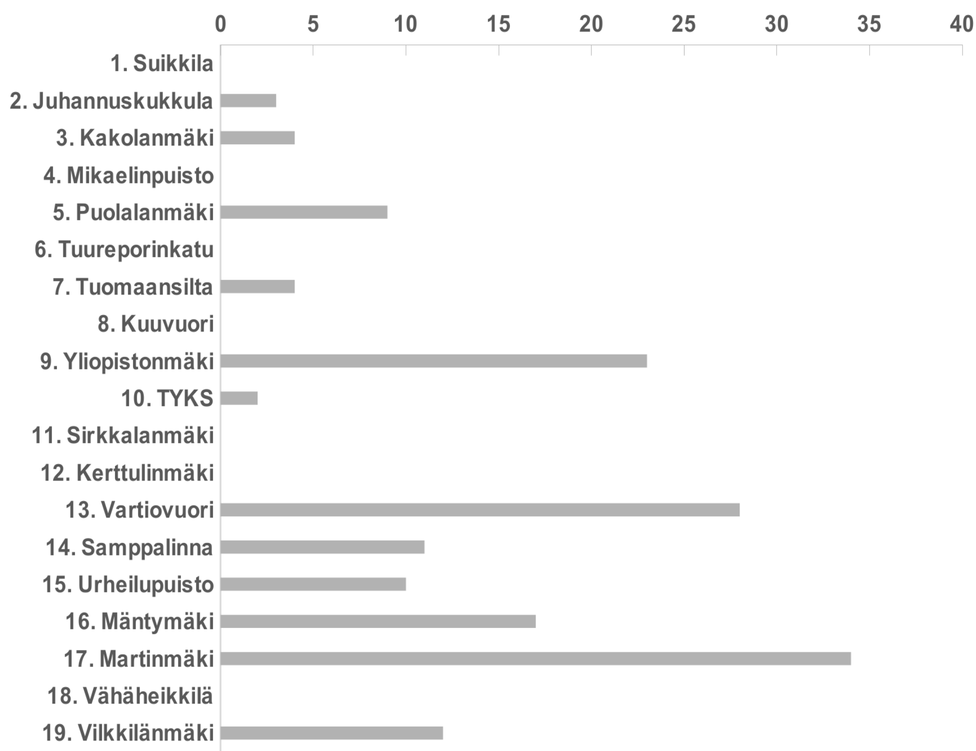

Figure 30. The number of analyzed building stones per hill demonstrating that the utilization of the hills on eastern part of the river (7–19) was much more active than the utilization of the hills on the eastern side of the river during the Middle Ages in Turku. On the basis of this study, the majority of building stones were acquired from the same side of the river.

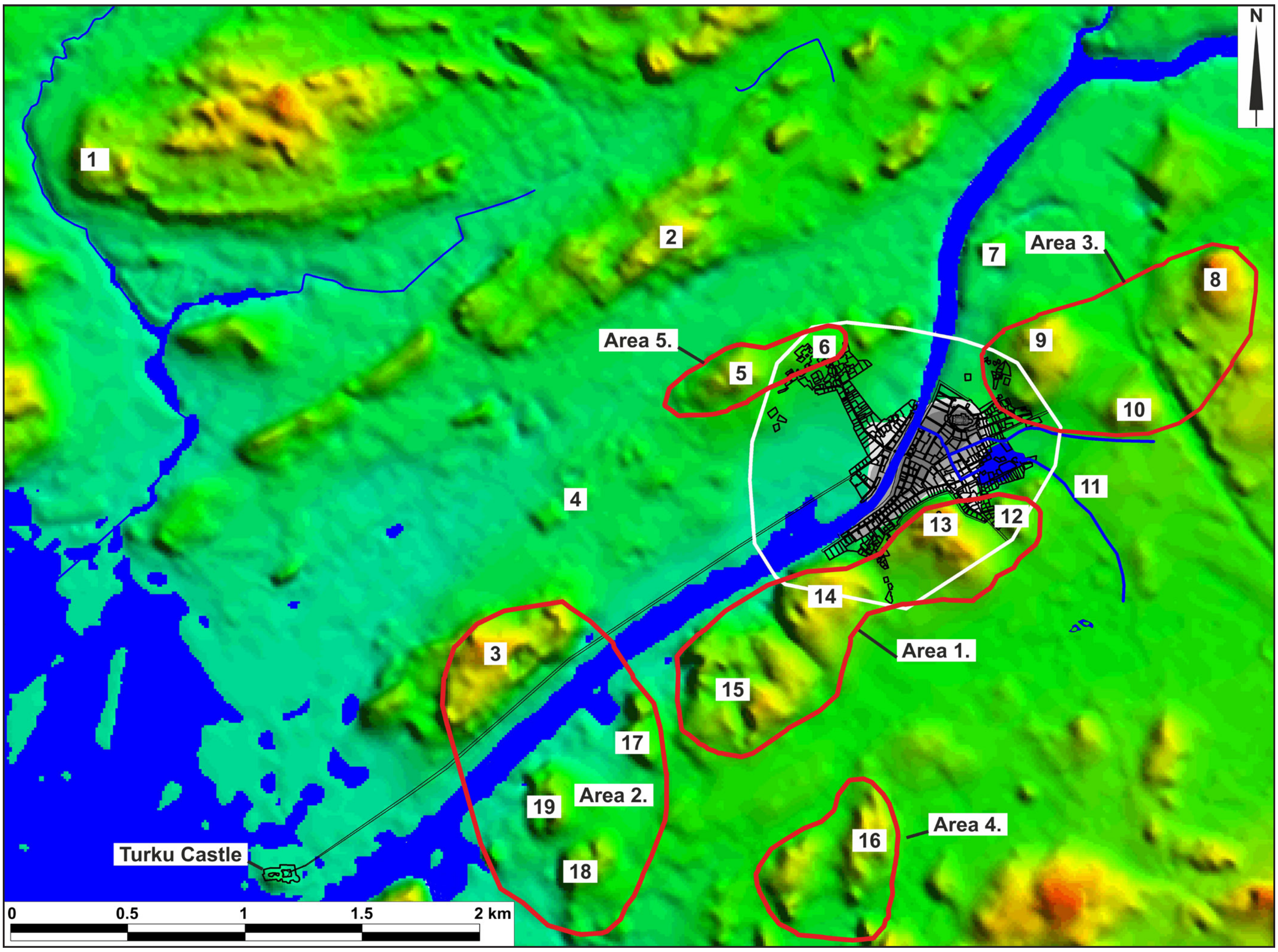

Figure 31. The hills that were possibly used for minor scale quarrying in the medieval Turku: 1. Suikkila, 2. Juhannuskukkula, 3. Kakolanmäki, 4. Mikaelinpuisto, 5. Puolalanmäki, 6. Tuureporinkatu, 7. Tuomaansilta, 8. Kuuvuori, 9. Yliopistonmäki, 10. Turku University Hospital (TYKS), 11. Sirkkalanmäki, 12. Kerttulinmäki, 13. Vartiovuori, 14. Samppalinna, 15. Urheilupuisto, 16. Mäntymäki, 17. Martinmäki, 18. Vähäheikkilä, and 19. Vilkkilänmäki. The possible quarrying areas discussed above (1–5) are circled with red. Water level + 2.65 m as in circa 1300 AD. The figure contains data from the Elevation model 2 m of National Land Survey of Finland.

Yliopistonmäki, TYKS, and Kuuvuori form an area where the main bedrock is granite (gray, hornblende, black red) commonly featuring dark mafic minerals. Granite forms wide lenses (hundreds of meters in diameter) in mica gneiss deposits. Mica gneiss, mica schist and especially garnet bearing kinzigite have commonly interbedded in granite, and also migmatites (including both granite and mica gneiss) are frequently found. Furthermore, the bedrock of these hills contains guartz-feldspar gneiss in minor quantities. All these hills were used for quarrying in the Middle Ages in Turku.

Mäntymäki is the closest possible place of origin for granodiorite first used in the 1390s (cellar K93:3).

Puolalanmäki and Tuureporinkatu form a mica gneiss area. Dark and fine grained mica gneiss was probably used at the end of the 15th century or at the beginning of the 16th century. Mica geiss dimension stones of notable sizes (cellars K94:11 and K94:12) originate possibly from the Puolalanmäki Hill, where the mica gneiss differs from strongly foliated and striped migmatitic gneisses interbedded with granites.

All in all, the number of stones used in masonry buildings seems to have been surprisingly low in Turku. Usually only the lowest parts of the walls were made of stones, and in many cellars brick was commonly used in the walls. This

Hill	Cellar	K92:6	K92:3	K92:5	K93:4	K93:5	K93:3	K95:21	K94:7
1	Suikkila								
2	Juhannuskukkula								
3	Kakolanmäki					3			1
4	Mikaelinpuisto								
5	Puolalanmäki								
6	Tuureporinkatu								
7	Tuomaansilta		2		2				
8	Kuuvuori								
9	Yliopistonmäki	2	1+3	6	1	3	1		1+1
10	TYKS					1		1	
11	Sirkkalanmäki								
12	Kerttulinmäki								
13	Vartiovuori	7+1					4	7	6
14	Samppalinna	3		1					
15	Urheilupuisto			6					
16	Mäntymäki		2			2	2		
17	Martinmäki	1	6		1	4		3	
18	Vähäheikkilä								
19	Vilkkilänmäki			11			1		

Table 5. The table presents the possible provenance of building stones used in different cellars. Plus sign indicates different stone types, which could have been acquired from the same hill.

may suggest favouring bricks over stones when possible. In each cellar, from two to six different stone types were used, and in total the number of different stone types in all of the analyzed twelve cellars was 52 (Table 3). The stones originate from different parts of Turku (Table 5 and Figure 31), and consequently there is no evidence of systematic quarrying from one area only. Possibly all easily available and suitable stones (including loose stones) have been used for building, since the bedrock in Turku is mostly difficult to quarry and hard to work. It is also possible that prehistoric stone cairns in this region were consumed as building stones. Although the Turku region was intensively inhabited in late prehistoric times, no cairns exist in this area, while the closest are found in the archipelago. The variability of stone types in single constructions, also suggests active reuse of materials.

It seems that after splitting the stones from bedrock, further finishing was not carried out, which also can be seen as an indication of the difficulties of working the hard stones. Therefore, it is perhaps slightly misleading to speak about dimension stones in this context. On the other hand, possible evidence of medieval stone splitting and working may have been destroyed or covered by later activities. During the fieldwork made for this study, dozens of clear drilling marks were detected in the bedrock outcrops, especially on the Vartiovuori Hill, indicating extensive quarrying activities. The marks on the hill, however, cannot be dated to the Middle Ages. Evidence of medieval stone working can be found in the northern façade of Turku Cathedral, where at least six large stones have clear drilling marks. The façade has been dated to the 1430s (Drake 2011), but the provenance of the stones has so far not been analyzed.

Since all available stone types from each cellar were included in this study, it seems that the variety of stone types used in different cellars was at the largest at the end of the 14th century and in the 16th century (Table 3 and Figure 32). The implementation of masonry technique took place at the end of the 14th century and the large variety

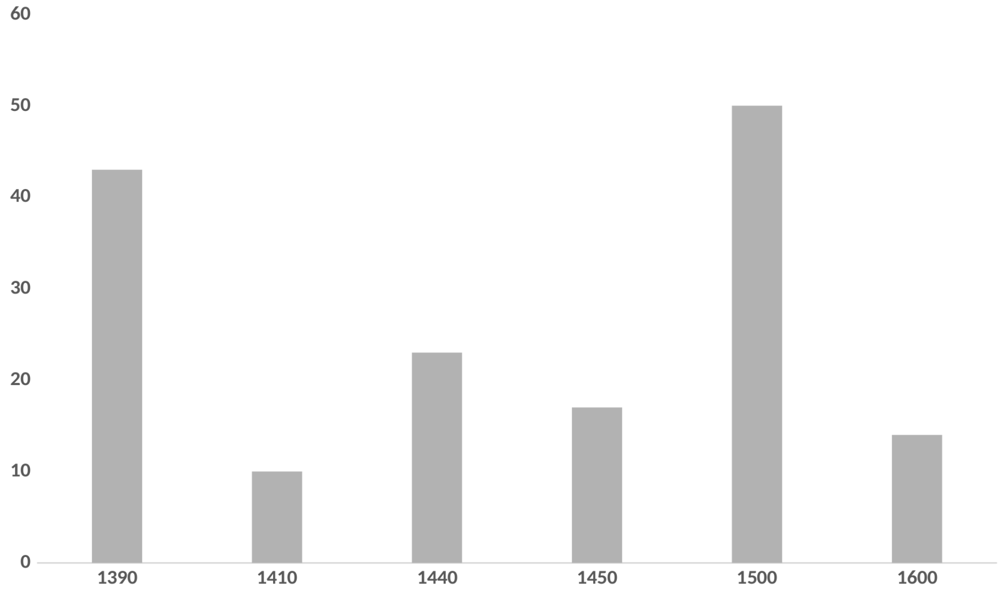

Figure 32. The number of analyzed building stones per constructions in different periods.

of stone types used in the oldest buildings may be related to problems in acquisition of stones and to limited skills and knowhow of the use of the local bedrock. This supports the idea that the builders of the first masonry buildings came from abroad.

In the 15th century, the variety of stones was more limited, which may indicate a more systematic use of local bedrock, increased understanding of the resources available, and organized acquisition of the material. This coincides with the boom in masonry building, the erection of new religious buildings and guildhalls, and the large-scale renovations in the town hall, cathedral, castle and Dominican convent (Seppänen 2012: 660–75; Niukkanen et al. 2014: 72, 74–5, 78–9, 81, 83, 86–8, 93–4; Seppänen 2016: 83–4). In the 16th century, the variety of different stone types seems to have increased. This can possibly be connected to destruction of old masonry buildings by fires (especially the one in 1546) and other wreckage in the early 16th century including measures catalyzed by the reformation, and active reuse of old material for repair work and new buildings (e.g. Seppänen 2016). However, in order to confirm these hypotheses, more systematic analyses of masonry buildings are needed from different periods and parts of the town.

Concluding remarks

The main aim of this study was to test the suitability of pXRF in analysing and tracing the provenance of building stones in Turku. Considering the limitations of the device, material, method and sampling, the results of the study are encouraging and provide a good basis for further discussions and studies related to the acquisition of stone materials and use of the environment in the past. The previous hypothesis suggesting local provenance of stone materials proved to be right, but in addition a much more detailed picture of the acquisition and use of stones was achieved by using this method.

The main problem limiting further research on building stones in Turku is the lack of available research material. This is caused by the fact that masonry constructions have in most cases either been demolished or covered without analyses of the material. Excavated masonry buildings have been filled and covered after documentation also in very recent past. If we want to get information of building stone provenance, the analyses of the stone material must be conducted while the excavations are on-going and while material is still available.

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Animal bones from medieval and early modern Saami settlements in Finnish Lapland

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Abstract

Publication of the rich medieval and early modern bone material excavated in Finnish Lapland over the past decades is long due. Bone assemblages can complete the picture of the life and livelihood of the early Saami societies presented in written sources. The data from three Saami dwelling sites and two market places, which are published here, support in many ways the written information, but show also some discrepancies between these two sources of information. The osteological data may raise more questions than they answer, but serve as an important source material for further research.

Keywords: Osteology, archaeological bones, Saami, reindeer, middle ages, economy

Introduction

Information about the livelihood of the medieval and early modern Saami communities in Finland is largely based on written sources. The famous works by Fellman (1907), Itkonen (1948a; 1948b) and Paulaharju (1922, 1927) are often used. However, these written sources describing the life and livelihood of Saami people during the period from medieval to early modern times, are often inaccurate and include many generalizations and misunderstandings (Lehtola 1997). The picture provided by the ethnographic literature is deficient, and archaeology is often the main method for studying the lives of Saami people in the past (Carpelan 1991). The largest find complex of the excavated sites is usually bones of animals utilized at the site. However, these rich bone materials from early modern sites in Finnish Lapland have not yet been fully exploited in research. Osteological data were used in a study discussing everyday life at two Saami market places, Markkina in Enontekiö and Pappila in Utsjoki (Lahti 2006; Harlin 2008a; Harlin 2009). Halinen (2009) discusses the Saami dwelling sites and their economies, but the associated osteological material is not included in detail. The osteological materials from Juikenttä were briefly mentioned by Carpelan (1992: 37).

Of all medieval and early modern sites in Norrland, Sweden, studied by Ekman and Iregren (1983), only Paulundsvallen in Lycksele contained a more significant number of unburnt bones. Further north, one mid-17th century silver mining community, Silbojokk, has been studied osteologically (Sten 1989). Since the Saami were transporting the goods to the community, the refuse fauna from the site reflects, to a large extent, the life and traditions of this ethnic group and, to a smaller extent, the life of the settlers (Sten 1989). On the Norwegian coast, by the Arctic Ocean, at a site called Gæccevaj'njar'ga 244 B, a medieval *goahti* (traditional Saami dwelling) has been studied osteologically (Hambleton & Rowley-Conwy 1997).The *goahti* provided a rather large bone material from a limited time period and was used to investigate the nature of the Saami economy at this point of time. In the Norwegian Arctic inland by Lake Vaggetem in Øvre Passvik (northeastern Norway) a 17th century house ground was studied to obtain a clearer picture of the eastern Saami population, their economy and their culture (Berg 2000; Magnell 2002).

In this paper we introduce the osteological data from three medieval – early modern Saami sites, Juikenttä and Autiokenttä 1 in Sodankylä/Soađegilli (northern Saami), and Nukkumajoki/Oađđiveadji 2 in Inari/Anár as well as from two winter markets, Pappila/Páhppal in Utsjoki/Ohcejohka and Markkina/Márkan in Enontekiö/Enodat. Our main aim is to make these analyses available for researchers studying the early livelihoods of the Saami, where the osteoarchaeological evidence can provide useful information. We restrict our discussion to the material itself; a major comparison of the osteological data versus ethnographic evidence and discussion of Saami identity and how it evolved in the past (e.g. Ojala 2009; Aikio 2012) are not the focus of this paper.

Saami villages and markets

The sites discussed in this paper are shown in Figure 1. Sodankylä lies in forest region of Lapland, Inari and Enontekiö near the boreal forest tree line, and Utsjoki clearly in the fell region. In

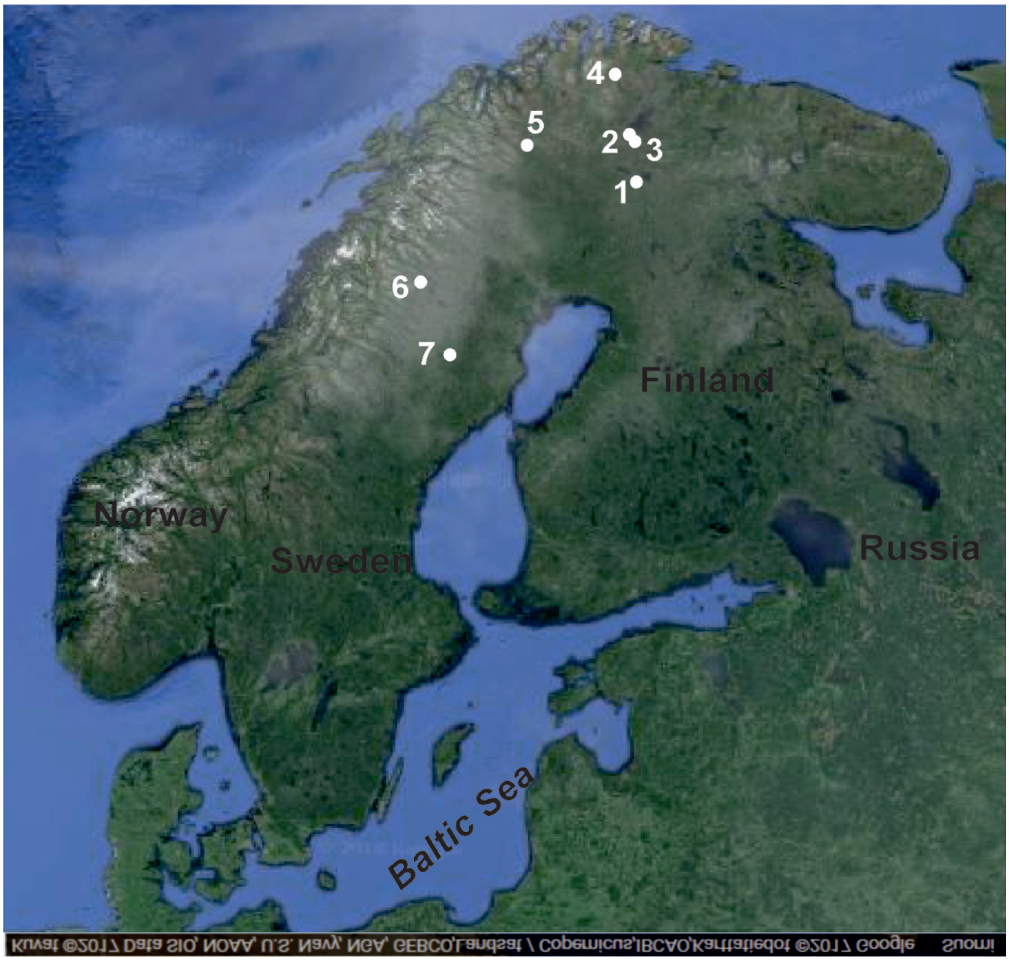

Figure 1. Medieval and early modern sites in northern Lapland discussed in the paper:

1 = Juikenttä in Sodankylä,
2 = Nukkumajoki in Inari,
3 =Autiokenttä 1 in Sodankylä,
4 = Pappila in Utsjoki,
5 = Markkina in Enontekiö,
6 = Silbojokk in Arjeplog,
7 = Paulundsvallen in Lycksele.

the whole area, the mean annual temperature lies below 0°C, and the mean snow depth is around 60–80 cm. The precipitation is highest in Sodankylä (Finnish Meteorological Institute (https://en.ilmatieteenlaitos.fi; read 16.8.2017).

Sodankylä Juikenttä (later Juikenttä) is the earliest of the five sites studied. The site was occupied by Kemi Saami from the Middle Ages to early modern times (AD 1050–1650) during the spring and early summer, as well as possibly also during the late summer (Carpelan 1987). These summer villages were situated near larger lakes or rivers, and fishing and fowling played important roles in the subsistence. According to written sources reindeer (*Rangifer tarandus*) herding was not generally practised in this area in the early phases of the studied time span. For example, in the reindeer register of Carl IX from 1609, only approximately twenty herders in current Utsjoki parish are listed with flocks with a maximum of twenty reindeer (see Hultblad model in Hansen & Olsen 2004: 206, fig. 40). In 1750, the number of taxed reindeer in Utsjoki area was several thousands (Itkonen 1948b: 115–7 and references within).

Reindeer were, however kept as draught animals. This is also suggested by the artefacts found during excavations (Carpelan 1987). The bone material from Sodankylä Juikenttä comes from a separate area not far from the Saami dwelling, *goahti*.

Inari Nukkumajoki 2 (later Nukkumajoki) is part of a series of large winter villages, occupied by the Saami during the 15–16th centuries (Carpelan 1991; Carpelan et al. 1994). Large quantities of bone were collected around the dwellings, along with bone and iron artefacts. Some artefacts suggest that the reindeer were not only hunted but also used as draught animals at this site (Carpelan 1991).

Sodankylä Autiokenttä 1 (later Autiokenttä) is the most recent of the studied Saami sites. It was occupied by Saami during the 17–18th centuries (Honkanen 1982), during a time when plague had diminished the domestic reindeer stock and the wild reindeer populations were growing (Paulaharju 1922; Itkonen 1948b: 93). The bone material of Autiokenttä comes from the cultural layers around and inside of a cottage and a *goahti* (Honkanen 1982).

Utsjoki Pappila (later Pappila) is located by the lake Mantojärvi/Máttajávri, which is a backwater of the Utsjoki/Ohcejohka river. The site was occupied between the 17th and 18th centuries based on the coins and clay pipes found in excavations. According to written sources, markets were already held at the Pappila site in 1640. The annual markets, taxation and court sessions here occurred at the end of February. A church was erected at the site in 1701 (Itkonen 1948a: 303; 1948b: 59). The Pappila site became the center for the Utsjoki siida (a Saami village, a traditional administration unit) and a center of trade for Tornio merchants or burghers. By 1820, the market came to an end due to competition from the nearby Arctic Ocean markets, such as Tanabru and Mortensnes, and the inland market site Inari (Itkonen 1948a: 206–8; 1948b: 203). According to written sources most of the Utsjoki siida practised reindeer herding in the 17th century. Otherwise, the subsistence was based on hunting. By the 18th century some of the inhabitants had cows and sheep. Agriculture was mainly pursued in the Teno area (Itkonen 1948a: 236; 1948b: 287). Fishing was practised on the Norwegian coast during the summer, and inland lakes were used in winter. Salmon fishing occurred on the river Teno, four kilometres from the site, or on its tributaries during spring, summer and autumn (Itkonen 1948a: 285).

The excavated area was limited to two *goahti* and a small area outside these structures. Adjacent to g*oahti* 2, there was a smaller structure, i.e., a so-called *buvri*, which used to be built as storage rooms or shelter for sheep or goats. If this structure can be interpreted as an animal shelter, it can imply an extended occupation at this site. At least this was the case among nomadic reindeer Saami in Deavddesvuopmi in Indre Troms, Norway. According to interviews, done in the 1990´s the Saami rented goats from the pesants in the spring and returned them in September. *Buvris* were built for this purpose (Sommerseth 2005: 100).

Enontekiö Markkina (later Markkina) lies at the confluence of three rivers. It was established as a market place by a royal order of King Carl the IX in 1604, and a church was erected there, probably in 1607. The Swedish crown controlled the taxation and markets from then on (Grape 1803: 219; Korpijaakko 1989: 139–141). Yearly markets were held at the site from the end of January to the beginning of February, which is also when taxation, annual court sessions and church services occurred (Bergling 1964: 129, 161–4). Markkina was the center of three siida – Rounala/Ruovdnal, Suonttavaara/Suovditvárri and Peltojärvi/Bealdojávri (Korpijaakko-Labba 1999: 103) – and an important market place for the Tornio burghers (Bergling 1964: 167; Clarke 1997: 258–287). According to written sources, the population of the Rounala *siida* already practised reindeer herding at the end of the 17th century, while that of Suonttavaara began herding at the beginning of 17th century, and finally, that of the Peltojärvi *siida* started herding by 1750 (Korpijaakko 1989: 132–6). The site was abandoned in 1826 when the church was moved further south (Itkonen 1948a: 73). The bone material comes from two cottages and three *goahti*. The site has been dated with the help of coins, clay pipes and dendrochronology.

Material, methods, and limitations of the data

The material used in this study consists of more than 20 000 analyzed bone fragments from 12 excavations (later samples) in the five villages and markets under study (Table 1 and Figure 1). The rich excavated bone material from Nukkumajoki (ca. 500 kg) as well as the fish scales from Juikenttä have been only partially analyzed. Our data are based on reports of osteological analyses carried out over several years by the authors, and other osteologists (Table 1). However, the bird bones from Juikenttä and Autiokenttä were reanalyzed for this paper (K. Mannermaa) and the results given here are based on these new analyses. Unfortunately, the bird material excavated from Markkina (Cottage 1, KM 26965) was not available for new analyses. Bird remains from different sites have been treated here as entities and materials from identifiable activity units (for example *goahtis*) have not been separated. Part of the material from Enontekiö and Utsjoki has been published previously by the first author (Lahti 2006).

All samples were highly fragmentary, since the long bones, phalanges and mandibles were chopped to extract bone marrow (Figure 2). Otherwise, the bones were fairly well preserved, showing little or no erosion.

The bones were analyzed morphologically by comparing them with modern skeletons in the collections of the Zoological Museum of the Finnish Museum of Natural History in Helsinki. In the new bird bone analyses, the identifications

Table 1. Early modern Saami sites included in the study. KM = The National Museum of Finland, Archaeological collections; SUG = The National Museum of Finland, Finno-Ugrian collections; NISP = Number of identified specimens; x = Fish scales, not counted. The osteological reports are stored in the archives of the Finnish Heritage Agency as well as at nba.fi.

Studied sites	Museum	Cat. no.	Structure	Excavator	NISP	Osteological analysis
Sodankylä 014 Juikenttä	SUG	5577	Separate pit	Carpelan 1962	1306	Ukkonen 1997a
Sodankylä 014 Juikenttä	SUG	5606	Separate pit	Carpelan 1964	541	Blomqvist ?; Mannermaa 2008a
Sodankylä 014 Juikenttä	SUG	5606	Separate pit	Carpelan 1964	11	Ukkonen 1997b
Sodankylä 014 Juikenttä	SUG	5625	Separate pit	Carpelan 1965	1231	Blomqvist ?; Mannermaa 2008b
Sodankylä 014 Juikenttä	SUG	5625	Separate pit	Carpelan 1965	x	Ukkonen 1997c
Inari Nukkumajoki	KM	20278	*Goahti*	Carpelan 1978	1880	Fortelius 1981
Inari Nukkumajoki	KM	20583	*Goahti*	Carpelan 1979	3490	Ukkonen 1996a
Sodankylä Autiokenttä 1	KM	20585	*Goahti* and cottage	Honkanen 1979	483	Ukkonen 1996b; Mannermaa2008c
Utsjoki Pappila	KM	33944	*Goahti* 1	Karjalainen 2003	3666	Lahti 2004
Utsjoki Pappila	KM	34678	*Goahti* 2	Karjalainen 2004	2803	Lahti 2005
Enontekiö Markkina	KM	25717	*Goahti* 2,3,4	Halinen 1990	2675	Ukkonen 1990
Enontekiö Markkina	KM	26965	Cottage 1	Halinen 1991	1815	Ukkonen 1991
Enontekiö Markkina	KM	32131	Cottage 2	Halinen 2000	194	Lahti, Mannermaa 2002a
Enontekiö Markkina	KM	32854	Cottage 2	Halinen 2001	525	Lahti, Mannermaa 2002b
				Total	20620	

Figure 2. Marrow-split reindeer phalanges, metacarpals, metatarsals and tibia from Inari Nukkumajoki 2 (KM 37149: 615). Photo Eeva-Kristiina Harlin.

of capercaillies (*Tetrao urogallus*) and black grouse (*Tetrao tetrix*) were based on morphological features and bone measurements (Erbersdobler 1968). Literature (Bacher 1967; Woelfle 1967) was used to aid in the identification of ducks (Anatinae), geese (Anserinae) and swans (*Cygnus* sp.). The species identification of young birds was based on the morphology, size and structure of the bone.

The NISP (number of identified specimens) was counted for all species and species groups. For reindeer and some bird species, the MNI (minimum number of individuals) was also calculated based on the amount of the most frequent non-replicated elements of these materials. Comparing MNI and MNE (minimum number of elements) would show if whole carcasses are present in the material or if some body parts are missing. This is very helpful when assumptions are made about the function of the site (Humbleton & Rowley-Conwy 1997: 57, Lyman 1994: 205–215). Unfortunately, the MNE was not calculated in most of the analyses.

The ages of the reindeer were roughly estimated based on the presence of deciduous teeth vs. M_3 (Bromée-Skuncke 1952) and the wear of the latter, as well as epiphyseal fusion following Hufthammer (1995). Hufthammer's data are derived from wild Norwegian (mountain) reindeer. These data are not directly applicable for assessing the ages of wild or semidomestic Finnish (mountain) reindeer, and the age assessments from the epiphyseal data have to be considered as estimates only. Unfortunately, not all samples contained the necessary information for these estimations. Too few specimens could be sexed to give any reliable information about the proportions of males to females among the slaughtered animals. Among the birds, the sex assessments of the capercaillie and the black grouse were based on the sizes of the bones.

The basic challenge when using analyses from several excavation sites, apart from the differences in excavation techniques and documentation, is the difference in methods used by individual osteologists. For example, osteometry was not a routine part of the original analyses, or if it was, the material included only a few measurable bones. One exception is Nukkumajoki 2 (KM 20278), where measurements were taken from several specimens, with astragali being the largest group of measured elements. However, one example of this challenge is that cutmarks have been documented only in a part of the analyses. Differences in the excavation techniques, documentation, and osteological methods, especially affect the quantitative results of the analyses. Some species groups, such as those of birds and fish, are often underrepresented in the analyses. The same applies to certain parts of the mammalian skeleton, such as the ribs and vertebrae. These differences limit the interpretation of the data, and make comparisons between the sites difficult.

Results

Mammals

Mammalian species found at the sites are given in Table 2. Reindeer – wild or semi-domestic – dominate the bone material at all sites. Wild mammals, such as wolf (*Canis lupus*), red or Arctic fox (*Vulpes vulpes/Alopex lagopus*), brown bear (*Ursus arctos*), wolverine (*Gulo gulo*), pine marten (*Martes martes*), European elk (*Alces alces*), Eurasian beaver (*Castor fiber*), red squirrel (*Sciurus vulgaris*), Norwegian lemming (*Lemmus lemmus*) and Arctic hare (*Lepus timidus*), are found occasionally in the samples. The water vole (*Arvicola terrestris*) found is probably from a later age; the species is known for its burrowing habits and is often found in refuse pits and middens as secondary deposit material. One seal (Phocidae) bone, the fourth metatarsus from the foot, was identified at Juikenttä. This is the only seal find in the studied materials.

Cattle (*Bos taurus*) and sheep/goat (*Ovis aries/ Capra hircus*) were present at Autiokenttä and the two market places Pappila and Markkina. Two pig bones (*Sus scrofa domesticus*) were found at Autiokenttä. Dog (*Canis familiaris*) remains seem to have been deposited only at Juikenttä. However, dog bite marks are present on reindeer bones from another excavation in Nukkumajoki (Harlin 2008b; analysis not available for this study).

Reindeer

NISP and the MNI of reindeer in all samples are given in Table 3.

Elements. Anatomical representations of reindeer bones are given in Figure 3 and Figure 4. Certain parts of the skeleton, such as the ribs, scapula, pelvis, sacral bone, humerus, femur, and patella derive from the meaty parts of the carcass. The radius, ulna, and tibia are also connected with some meat, but the cranium, mandible, atlas, axis, carpal bones, tarsal bones, metacarpus, metatarsus, phalanges, and sesamoidal bones are hardly related to any meat. Among these bones, the metapodial bones and mandibles have special values because of the quantity of fatty bone

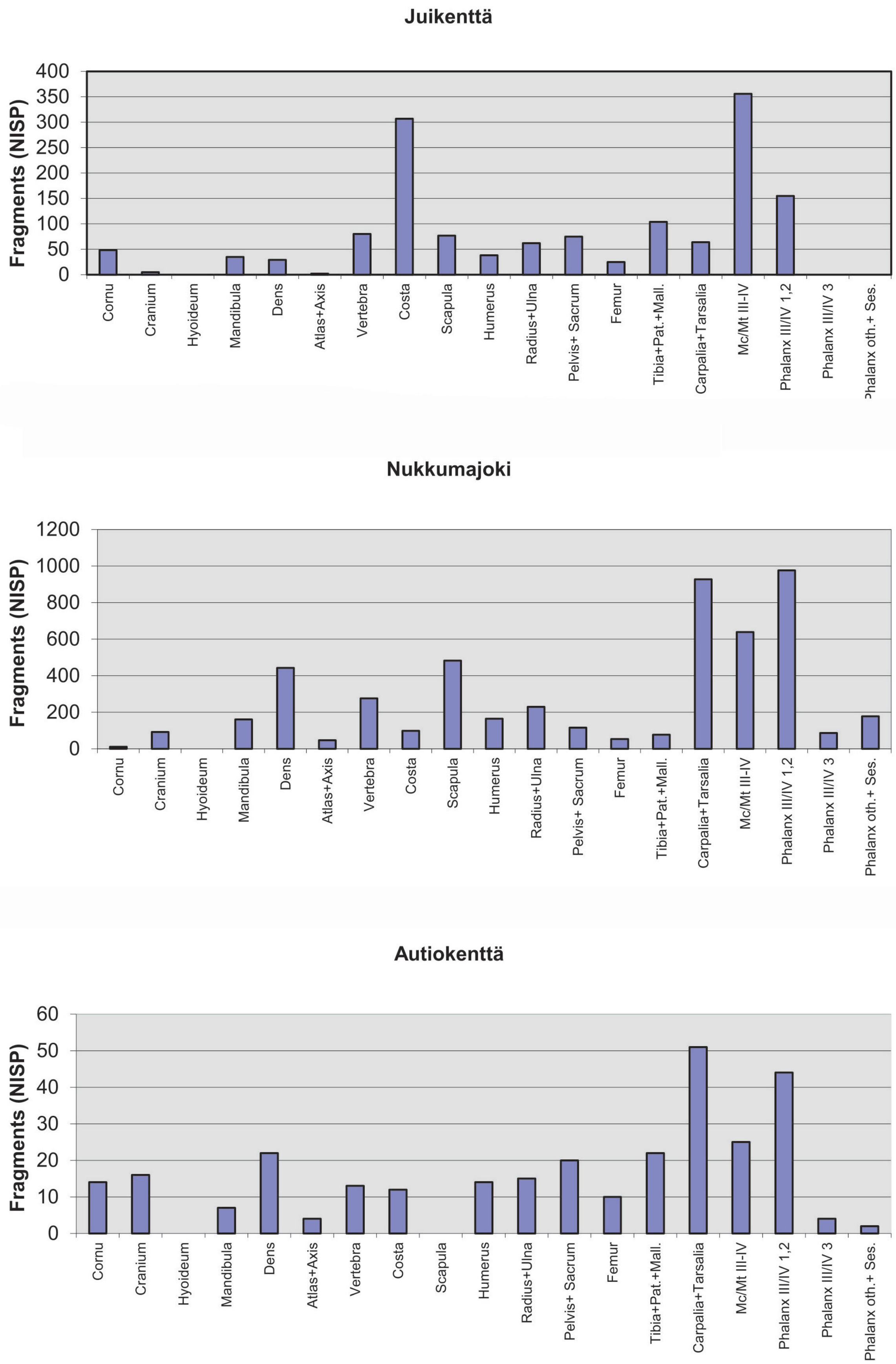

Figure 3. Anatomical distribution of the reindeer bones at the medieval to early modern Saami dwelling sites Juikenttä, Nukkumajoki and Autiokenttä. In the material from Juikenttä, all ribs were identified as being from reindeer, while at the other sites, higher taxa (Ruminantia, Artiodactyla, Mammalia) were used for identification when no specific diagnostic features were present in the ribs.

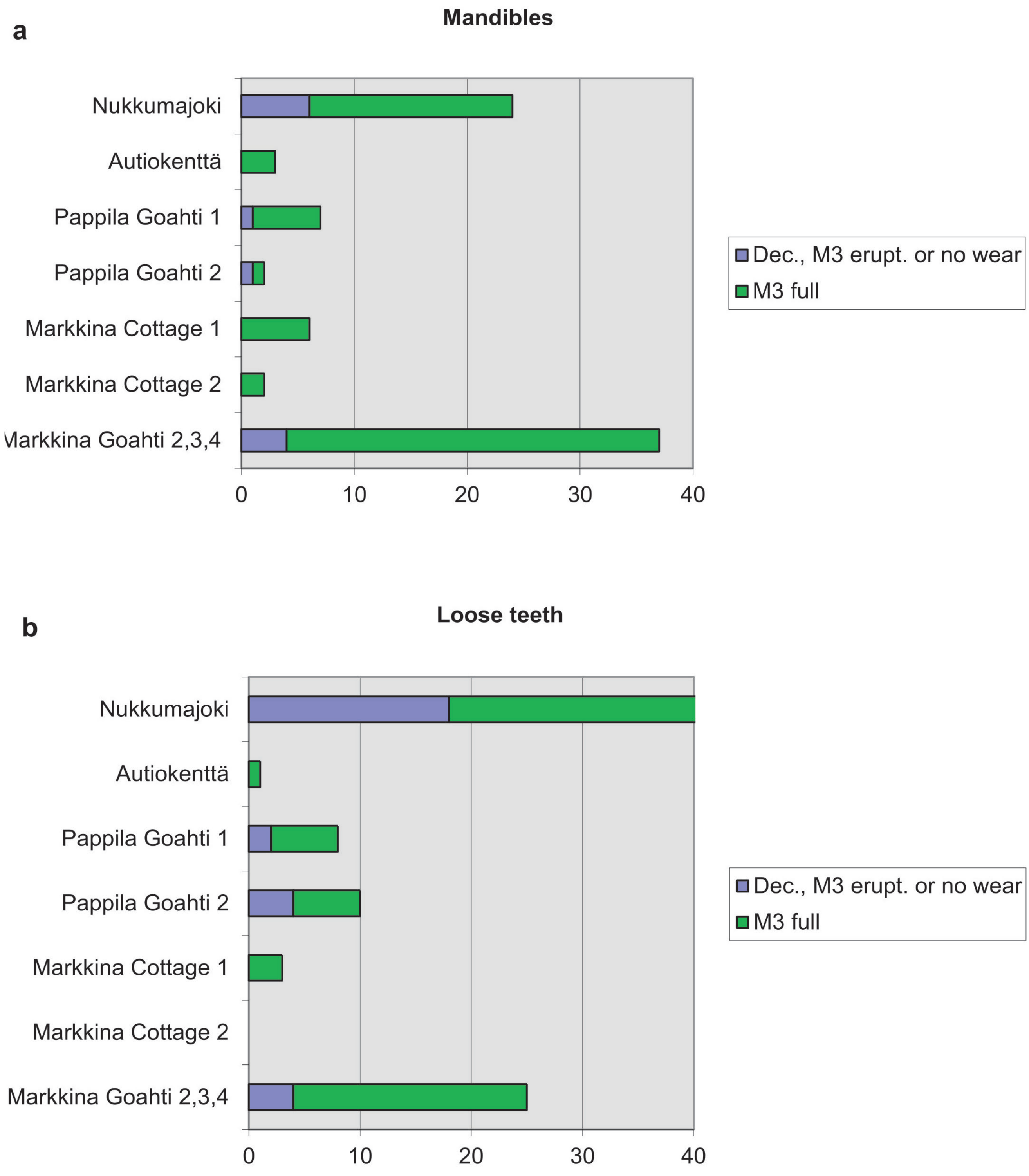

Figure 4. Anatomical distribution of the reindeer bones at the medieval to early modern Saami market places of Pappila and Markkina.

Table 2. Mammalian species identified from bone materials found at the medieval to early modern Saami sites Sodankylä Juikenttä (AD 1050–1650), Inari Nukkumajoki (AD 1480–1580), Sodankylä Autiokenttä (AD 1600–1700), Utsjoki Pappila (AD 1600–1700), and Enontekiö Markkina (AD 1604–1826). Quantification based on NISP (Number of identified specimens).

	Juikenttä	**Nukkumajoki**	**Autiokenttä**	**Pappila**	**Markkina**
Bos taurus (cattle)			56	11	18
Ovis/Capra (sheep/goat)			7	63	49
Sus scrofa (domestic pig)			2		
Canis familiaris (domestic dog)	9				
Canis lupus (wolf)				1	
Vulpes vulpes (red fox)			7		4
Ursus arctos (brown bear)			1		
Gulo gulo (wolverine)	1	1			
Martes martes (pine marten)	1	1			
Phocidae (seals)	1				
Alces alces (European elk)	1			1	14
Rangifer tarandus (reindeer)	1460	5355	301	1927	1604
Castor fiber (beaver)	13	5	1	1	
Sciurus vulgaris (red squirrel)			2		7
Arvicola terrestris (water vole)	1				
Lemmus lemmus (Norwegian lemming)					2
Lepus timidus (Arctic hare)				2	
Total	1488	5362	377	2006	1704

Table 3. Reindeer bones identified from bone materials found at the medieval to early modern Saami sites Sodankylä Juikenttä (AD 1050–1650), Inari Nukkumajoki (AD 1480–1580), Sodankylä Autiokenttä (AD 1600–1700), Utsjoki Pappila (AD 1600–1700) and Enontekiö Markkina (AD 1604 - 1826). KM = The National Museum of Finland, Archaeological collections; SUG = The National Museum of Finland, Finno-Ugrian collections; NISP = Number of identified specimens; MNI = Minimum number of individuals.

Studied sites	**Museum**	**Cat. no.**	**Structure**	**NISP Total**	**NISP *Rangifer***	**MNI *Rangifer***
Juikenttä	SUG	5606	Separate pit	552	435	-
Juikenttä	SUG	5625	Separate pit	1230	1025	-
Nukkumajoki	KM	20278	*Goahti*	1880	1869	44
Nukkumajoki	KM	20583	*Goahti*	3490	3476	62
Autiokenttä 1	KM	20585	*Goahti*, cottage	483	301	6
Pappila	KM	33944	*Goahti* 1	3666	988	19
Pappila	KM	34678	*Goahti* 2	2803	939	13
Markkina	KM	25717	*Goahti* 2,3,4	2675	1392	18
Markkina	KM	26965	Cottage 1	1815	576	11
Markkina	KM	32131	Cottage 2	194	80	5
Markkina	KM	32854	Cottage 2	525	158	3

Table 4. Number of reindeer antler fragments identified from bone materials found at the medieval to early modern Saami sites Sodankylä Juikenttä (AD 1050–1650), Inari Nukkumajoki (AD 1480–1580), Sodankylä Autiokenttä (AD 1600–1700), Utsjoki Pappila (AD 1600–1700) and Enontekiö Markkina (AD 1604–1826).

Site	Skull with antlers	Skull with shed antlers	Shed antlers	Antler fragments
Juikenttä (KM 5606)	0	?	?	17
Juikenttä (KM 5625)	1	?	?	31
Nukkumajoki 2 (KM 20583)	0	3	0	5
Nukkumajoki 2 (KM 20278)	0	2	0	6
Autiokenttä (KM 20278)	0	3	1	13
Pappila (KM 34678)	1	0	0	12
Pappila (KM 33944)	1	0	1	22
Markkina (KM 26965) Cottage 1	3	0	0	23
Markkina KM 32131, 32854) Cottage 2	2	0	0	56
Markkina (KM 25717) Goahti 2	0	0	0	4
Markkina (KM 25717) Goahti 3	2	0	0	10
Markkina (KM 25717) Goahti 4	0	0	1	10

marrow in them. Additionally, cloven hoofs are of increased value due to their thick fat layers.

Bones from all body parts were found at all of the sites. Lower parts of the extremities (carpals and tarsals, metapodial bones and phalanges) are typically the most abundant elements at all sites. At Pappila, an exceptionally high proportion of femurs is noted. However, the proportion of humeri here is approximately the same as at the other sites. Pappila and the *goahti* from Markkina show notably high proportions of mandibles and teeth in comparison to those of the other sites. In Juikenttä, the proportions of carpals and tarsals are exceptionally low, and the proportion of ribs is high. This particularity may be due to different analysis practices: at other sites, ribs were not identified by species, but higher taxa (Ruminantia, Artiodactyla, and Mammalia) were used when no specific diagnostic features were present.

Age and size. Based on teeth eruption and wear, most of the slaughtered animals were young adults. Individuals with deciduous teeth, M_3 just erupting or M_3 without any wear (younger than sixteen months; Bromée-Skuncke 1952) were present in all larger samples but were abundant only at Nukkumajoki. Individuals with fully erupted third molars (sixteen months or older) were much more common (Figure 5). There is no noticeable difference between the teeth attached to mandibles and loose teeth. Heavily or totally worn rows of teeth were found only at the market places of Pappila and Markkina (Figure 6). However, the proportions of the different wear stages are quite different when the loose teeth are considered. Teeth wear is known to correlate with the age of an individual but also correlates with the diet (lichen vs. more abrasive hay).

The analysis of the epiphyseal fusion of the bones confirms the scarcity or absence of younger individuals (under eighteen months) among the slaughtered animals (Figure 7), and even the next age group seems small.

The sample with the National Museum of Finland (KM) number 20278 from Nukkumajoki included 44 measurable astragali (Figure 8). Unfortunately, the measuring technique was different from the methods used today and does not allow for comparisons with data from other Saami sites (Magnell 2002).

Antlers. Surprisingly few antler fragments were identified in the samples, with the only exception being cottage 2 in Markkina (Table 4). Most of the specimens were fragments of the shaft, but some had their proximal ends intact or were attached to a skull. Reindeer bulls shed their antlers in November, after the rutting season. Castrates may, however, retain their antlers over the winter. Cows shed their antlers after calving, approximately in May. The growth of new antlers begins in the spring for both sexes.

At the markets of Markkina and Utsjoki, nearly all identifiable antler basal parts were attached to skulls, and therefore, either they derive from females or castrates or the occupation of the sites was not restricted to the winter months. At the dwelling sites of Autiokenttä and Nukkumajoki, the opposite is true. Here, individuals with shed antlers must have been killed during the first half of the year (males) or during the short period after calving (females). No individuals with shed antlers should be present in a reindeer population during the summer months.

Domestic species

Direct evidence of animal husbandry can be found at Autiokenttä, where a relatively high number of cattle, sheep/goats, and domestic pigs were identified. Domestic species were also present at both market places, Pappila and Markkina, but in very low numbers (Figure 9). Domestic dogs were present only at Juikenttä.

The anatomical distribution of the excavated cattle bones (Figure 10) imply that, at Autiokenttä, not only the meaty parts (ribs, upper extremities) but also the less meaty parts (lower extremities) were used. Furthermore, elements connected with hardly any meat, such as the head and the lowest extremities, are found in the excavated material. The number of cattle bones from Pappila and Markkina is low, but fragments of the skull and mandible, as well as loose teeth, are present at both sites. Most of vertebrae and ribs were identified only by being of the taxa Ruminantia or Mammalia, which explains the absence of these bones in the anatomical presentation.

At Autiokenttä, nearly all sheep or goat bones are derived from the head region (Figure 10). At Pappila and Markkina, the distribution is quite the opposite; bones associated with meaty parts clearly dominate the material.

Birds

The bird species identified in the samples are given in Table 5. The sample from Juikenttä stands out from all other sites in regard to both the number of identified fragments and taxonomic diversity. The predominant species is capercaillie, followed by the whooper swan (*Cygnus cygnus*) and geese. Interestingly, Juikenttä is the only site in our study where whooper swan was identified. In addition to anatid and tetraonid birds the sample from Juikenttä includes species that are not typically identified in the Finnish refuse faunas (Mannermaa 2003), such as the crane (*Grus grus*), the great cormorant (*Phalacrocorax carbo*), and the Northern goshawk (*Accipiter gentilis*).

The material from the Nukkumajoki dwelling site contains hardly any bird bones, and bones identified at Autiokenttä belong almost exclusively to one species, the capercaillie. The bone sample from the market place Pappila

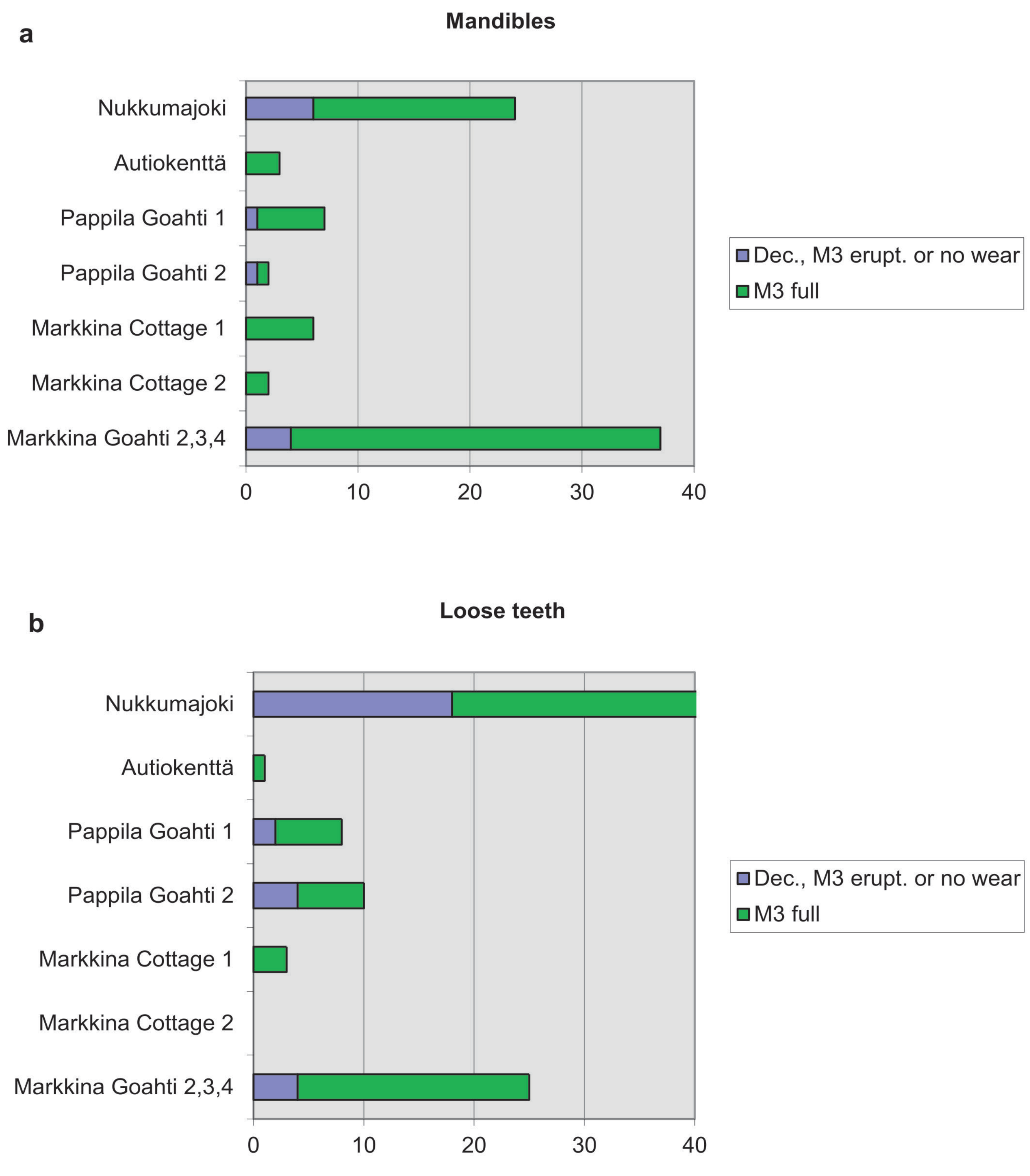

Figure 5. Juvenile reindeer bones in samples from Nukkumajoki, Autiokenttä, Pappila and Markkina. The numbers of deciduous teeth and M3 with no wear are compared to that of fully erupted M3. a = in mandibles, b = loose teeth.

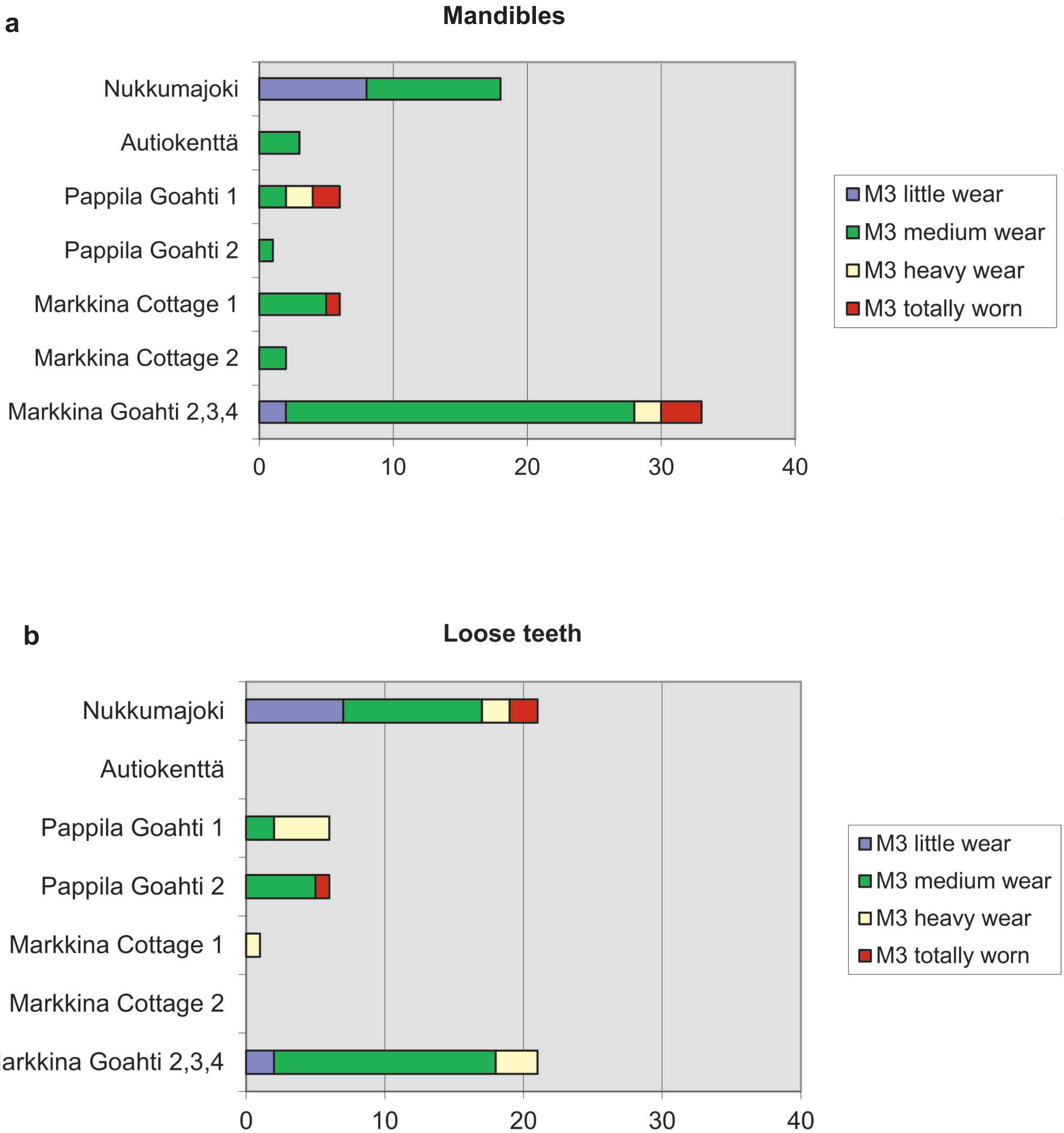

Figure 6. Proportions of the different stages of wear of the reindeer M3 in the bone samples from Nukkumajoki, Autiokenttä, Pappila and Markkina. a = in mandibles, b = loose teeth.

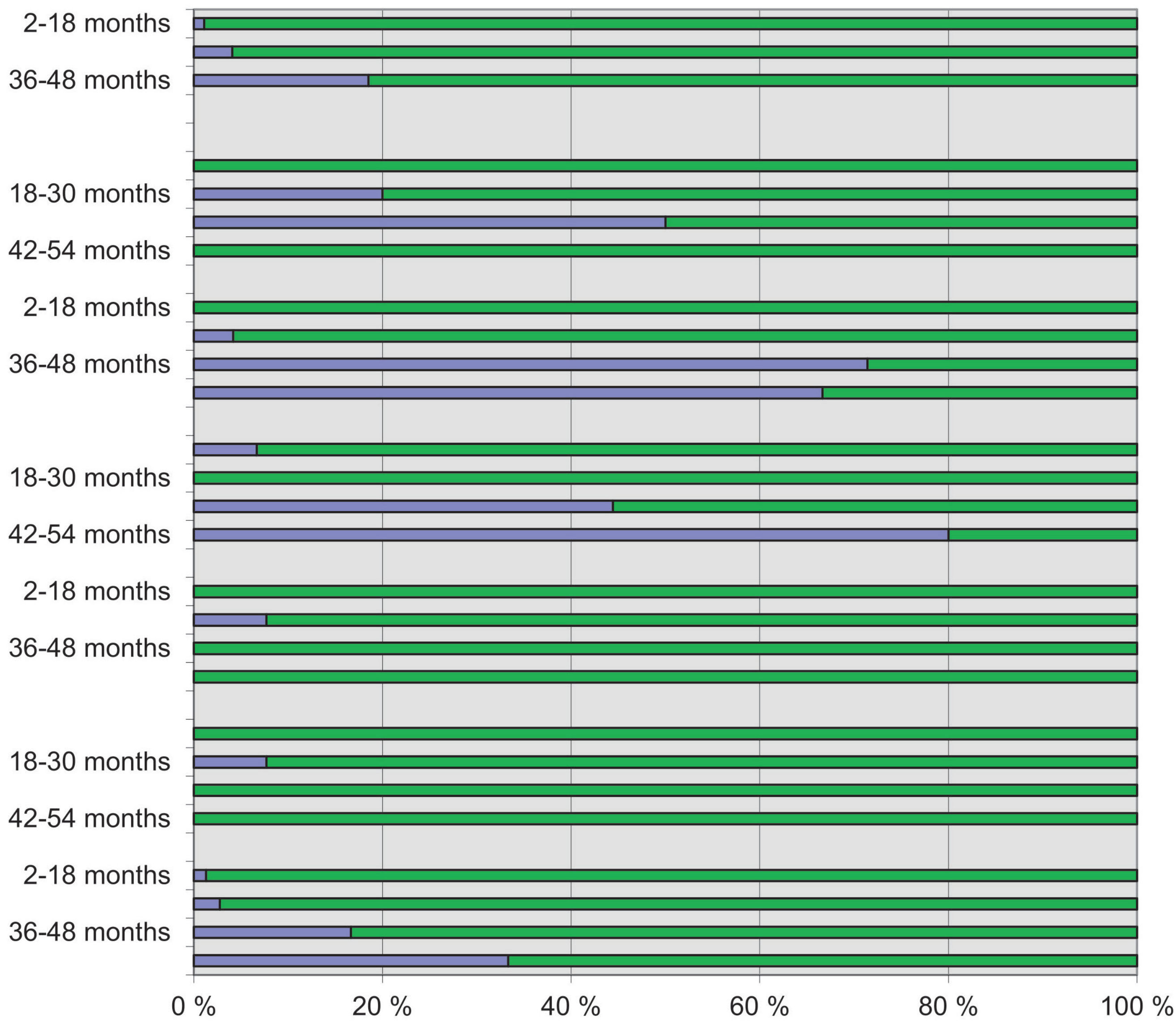

Figure 7. Proportions of unfused/fused epiphyses of the selected elements from the reindeer bone samples from Nukkumajoki, Autiokenttä, Pappila and Markkina. The time-of-fusion is based on Hufthammer (1995).

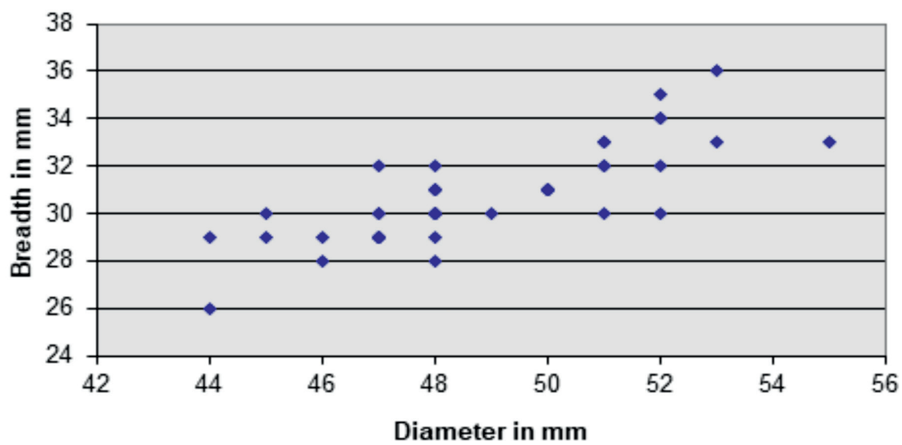

Figure 8. Size distribution of the astragali in the reindeer bone samples from Nukkumajoki.

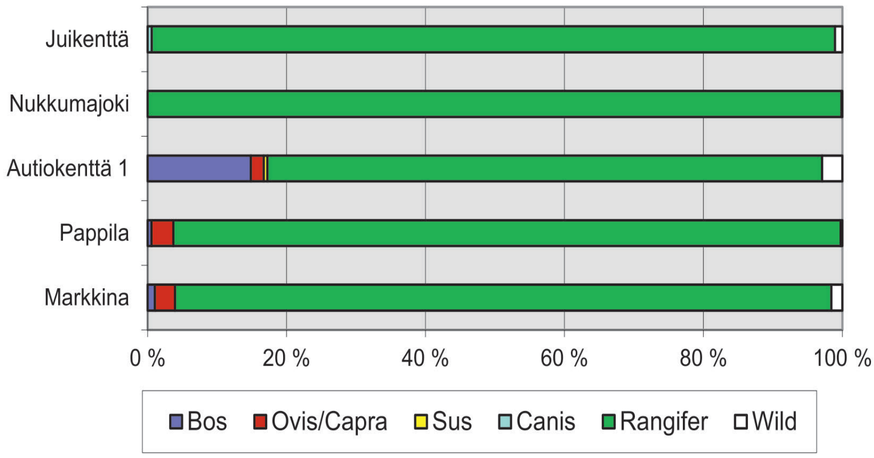

Figure 9. Proportions of domestic animal, reindeer and wild mammalian species in the bone samples from the medieval to early modern Saami sites Juikenttä, Nukkumajoki, Autiokenttä, Pappila and Markkina.

contains practically only bones from the genus *Lagopus* (either willow grouse *L. lagopus* or rock ptarmigan *L. muta*). The material from Markkina contains a high number of bird bone fragments, but the number of species is much lower than in Juikenttä. The main bird groups at Markkina are the genus *Lagopus* and mid-sized ducks.

The anatomical distributions of bird bones from Juikenttä, Autiokenttä, Markkina and Pappila are shown in Figure 11. Nukkumajoki has been omitted from this analysis because of the small size of the sample. Here we have included the 17–18th century Saami site Lycksele in central Sweden (Zachrisson 1976: 87; Ekman & Iregren 1984) in the analysis. In general, bones from the shoulders and wings are the most abundant bones at all sites. The humerus is by far the most common element at Juikenttä and Autiokenttä. It is also common at Markkina and Pappila, but not with the same intensity as at Juikenttä and Autiokenttä. The axial bones and cranium are present but not pronounced at all samples. An exception to this is the number of vertebrae at Markkina and the fragments from the sternum at Autiokenttä and Markkina.

The amount of material from Autiokenttä is small, which may be the ultimate reason for the total absence of some elements. At Juikenttä, however, the reason for the strikingly low number of scapulae must lie elsewhere. In bird bone samples, it is often typical to have a more or less equal number of specimens of the scapulae and coracoidii, as they are tightly connected to each other by ligaments.

Figure 12 shows the anatomical distribution of the elements from different parts of the carcasses in specific taxonomic bird groups. In this analysis, Nukkumajoki and Autiokenttä are left out because of their low sample size. At Juikenttä, the number of wing elements is pronounced for all bird groups, especially for swans and geese. At all other sites, the proportions of leg and wing elements are much more equal.

Sex could be assessed only for six capercaillies (three females and three males), as well as one black grouse (male) from Juikenttä. The sample from Juikenttä included also a handful of bones from juvenile birds. One juvenile bird could be identified as a whooper swan and three as some large species of goose (*Anser anser/Anser fabalis*). No cut marks or other marks which could imply butchering or other handling methods could be recognized on the bird bones. The surfaces of some of the *Lagopus* bones at Pappila were deformed, which may indicate boiling or chewing.

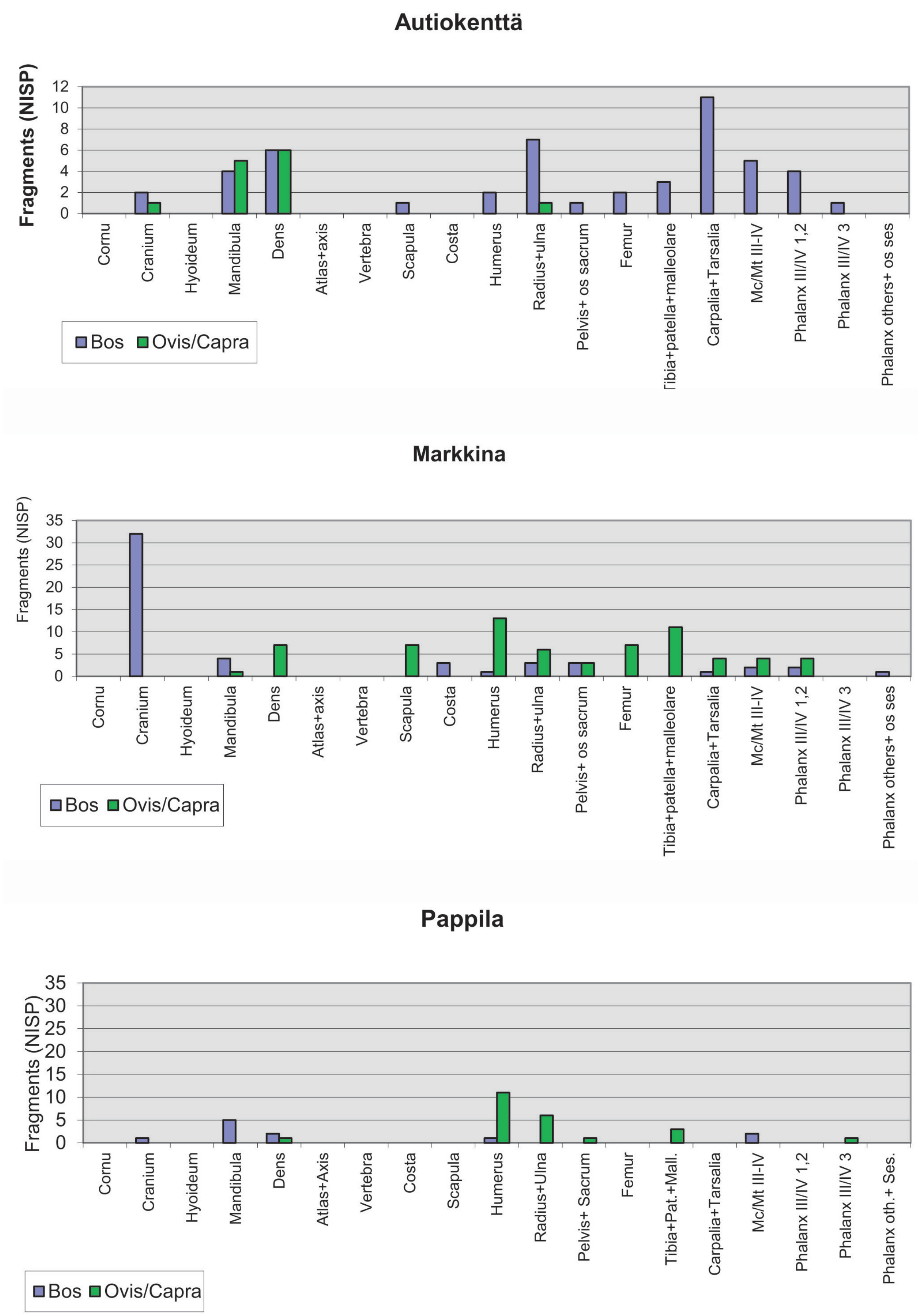

Figure 10. Anatomical distributions of cattle and sheep/goat bones at the medieval to early modern Saami sites Autiokenttä, Markkina and Pappila.

Table 5. Bird species identified from the bone materials found at the medieval to early modern Saami sites Sodankylä Juikenttä (AD 1050–1650), Inari Nukkumajoki (AD 1480–1580), Sodankylä Autiokenttä (AD 1600–1700), Utsjoki Pappila (AD 1600–1700) and Enontekiö Markkina (AD 1604–1826). Quantification based on NISP (Number of identified specimens).

	Juikenttä	Nukkumajoki	Autiokenttä	Pappila	Markkina
Anatidae					
*Cygnus cyg*nus (whooper swan)	66				
Cygnus Cygnus/Anser fabalis/A. anser whoper swan/ greylag goose/bean goose	2				
Cygnus Cygnus/Grus grus (whooper swan/common crane)					
Anser anser/Anser fabalis (greylag goose/bean goose)	41				4
Anser sp. /*Branta* sp. (geese)	32				
Anas crecca (teal)	2				
Anas crecca/A. querquedula (teal/garganey)	1				
Anas platyrhynchos (mallard)					2
Anas sp. (indet. duck)					
Clangula hyemalis? (long-tailed duck?)	2				
Clangula hyemalis/Aythya sp. (long-tailed duck/*Aythya*)	1				
Aythya sp. (diving ducks)					6
Mergus serrator (red-breasted merganser)	1				7
Mergus merganser (goosander)	2				
Mergus sp.?	1				
Melanitta nigra? (velvet scoter?)	1				
Melanitta sp. (velvet scoter/common scoter)	1				
Melanitta sp./*Mergus* sp.	1				
Bucephala clangula (goldeneye)	1				1
Anatidae (anatid birds)	22		2	2	96
Tetraonidae					
Bonasa bonasia (hazel grouse)					3
Lagopus lagopus? (willow grouse?)	1				
Lagopus lagopus/L. mutus (willow grouse or ptarmigan)	2			122	110
Tetrao tetrix (black grouse)	7				
Tetrao tetrix? (black grouse?)	2				
Tetrao urogallus (capercaillie)	71	2	37		
Tetrao urogallus? (capercaillie?)	2				
Tetrao tetrix/Tetrao urogallus (black grouse/capercaillie)	7		9		
Tetraonidae (Tetraonid birds)		1		2	
Others					
Gavia arctica (black-throated diver)					1
Gavia stellata (red-throated diver)	1				
Gavia arctica/Gavia stellata (black-throated diver/red-throated diver)	4	1			
Podiceps cristatus/P.grisegena (red-necked grebe/great crested grebe)	1				
Phalacrocorax carbo (cormorant)	1				
Aquila chrysaetos/Haliaeetus albicilla (golden eagle/white-tailed sea-eagle)	2				
Accipiter gentilis? (northern goshawk?)	1				
Grus grus (common crane)	5				
Philomachus pugnax (ruff)					6
Charadriidae (indet. wader)			1		
Aves	5			35	73
TOTAL	**311**	**4**	**49**	**161**	**309**

Fish

Fish are not as abundant in the material as could be expected (Table 6). This may be due to the excavation methods and analysis techniques, such as the excavated soils not being sieved or the small fragments of ribs and vertebrae not being counted. Pike (*Esox lucius*) and perch (*Perca fluviatilis*) are common in the fish material, as at nearly all Finnish archaeological sites. Cyprinid fish are common only at Juikenttä and salmonid fish at Markkina. At both of the market places, Pappila and Markkina, cod (*Gadus* sp.) was also found among the fish bones. The nearest populations of this salt-water fish are found in the North Atlantic and Arctic Oceans, relatively near the sites.

The category Teleostei includes mainly fragments of ribs, fin rays and vertebrae, which were not identified by species. It is possible that the number of salmonids would grow considerably if all vertebrae were analyzed by a fish expert. The preservation of fish bones varies by element and species. Pike, for instance, leave many identifiable fragments from the head region, where as salmon can often be identified only by their vertebrae.

The material from Juikenttä contained vast numbers of fish scales, but only some of them were analyzed. All scales analyzed so far belong to perch.

Discussion

Reindeer hunting or herding

The origin and spread of reindeer herding in northern Fennoscandia is currently a subject of intensive discussion and research (Sommerseth 2005: 97; Bjørnstad & Røed 2009; Bjørnstad et al. 2011; Salmi 2017; Bergstøl 2018; Núñez 2018; Salmi *et al*. 2018). At this point, no consensus has been reached by the researchers (Andersen 2005: 6; Bjørklund 2013: 174–6). In general, the livelihood of the Saami people has evolved from hunting wild reindeer through small scale reindeer herding to full scale reindeer nomadism. These changes are usually associated with changes in the social structure of a society. Hunting was practised in *siida* where the catch was divided between all members. A skilful hunter was a valued member of society, and the desired resource was the hunted animal (e.g. Hansen & Olsen 2004: 203–214). With the transition to reindeer herding, the herded animals became property, which were accumulated by private members of the society. The society became hierarchical, and previously common resources became private (e.g., Ingold 1980; Vorren 1980; Olsen 1984; Hansen & Olsen 2004: 207–8; Andersen 2005: 7).

According to written sources, reindeer herding was practised by *siidas* connected to both markets, Markkina and Pappila, but not by the inhabitants of Juikenttä, Nukkumajoki or Autiokenttä at the time of their occupation (Hansen & Olsen 2004: 40). According to Magnell (2002), in osteological assemblages, a large body size and the dominance of older rather than younger individuals is interpreted as evidence of hunting of wild reindeer, while a small body size and the presence of juveniles is thought to suggest reindeer herding. This is true in a domestic, meat-based economy where mostly young and sub-adult animals are slaughtered (Hambleton & Rowley-Conwy 1997: 68). Earlier, however, the favourable animals to be slaughtered were one and a half years old castrates and old females (Jomppanen & Näkkäläjärvi 2000: 83, Soppela 2000: 93). Hambleton and Rowley-Conwy (1997)

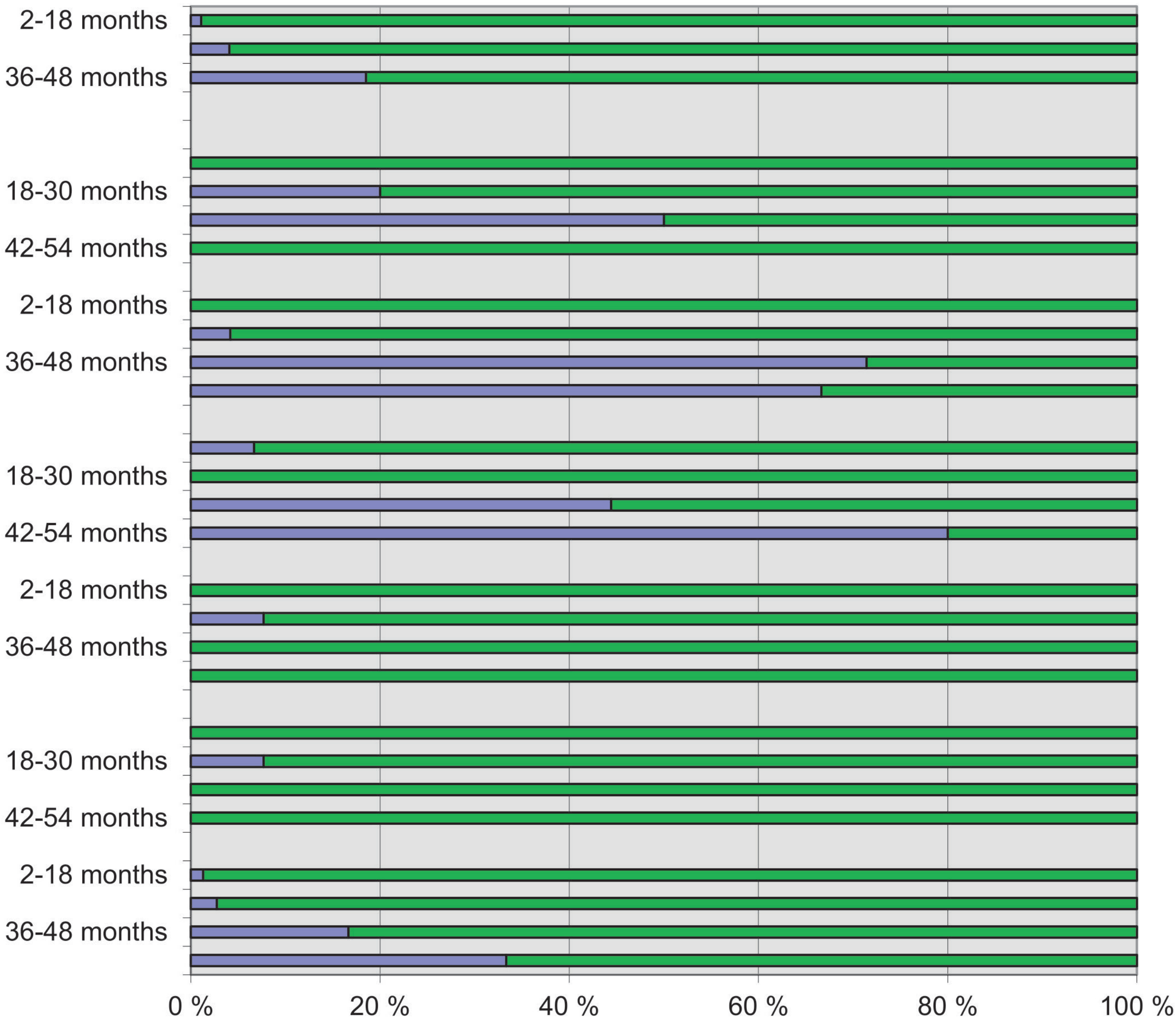

Figure 11. Anatomical distribution (in percent) of the bone types from Juikenttä, Autiokenttä, Markkina and Pappila.

Table 6. Fish species identified from the bone materials found at the medieval to early modern Saami sites Sodankylä Juikenttä (AD 1050–1650), Inari Nukkumajoki (AD 1480–1580), Sodankylä Autiokenttä (AD 1600–1700), Utsjoki Pappila (AD 1600–1700) and Enontekiö Markkina (AD 1604–1826). Quantification based on NISP (Number of Identified Specimens).

	Juikenttä	**Nukkumajoki**	**Autiokenttä**	**Pappila**	**Markkina**
Cyprinidae (cyprinid fish)	55				
Coregonus sp. (whitefish)		1		1	16
Salmonidae (salmonid fish)		1		35	1
Coregonidae/Salmonidae					49
Esox lucius (pike)	176	9	2	6	9
Gadus sp. (cod)				27	34
Lota lota (burbot)					3
Perca fluviatilis (perch)	58*		3		31
Teleostei	853			151	552
Total	**1142**	**11**	**5**	**220**	**695**

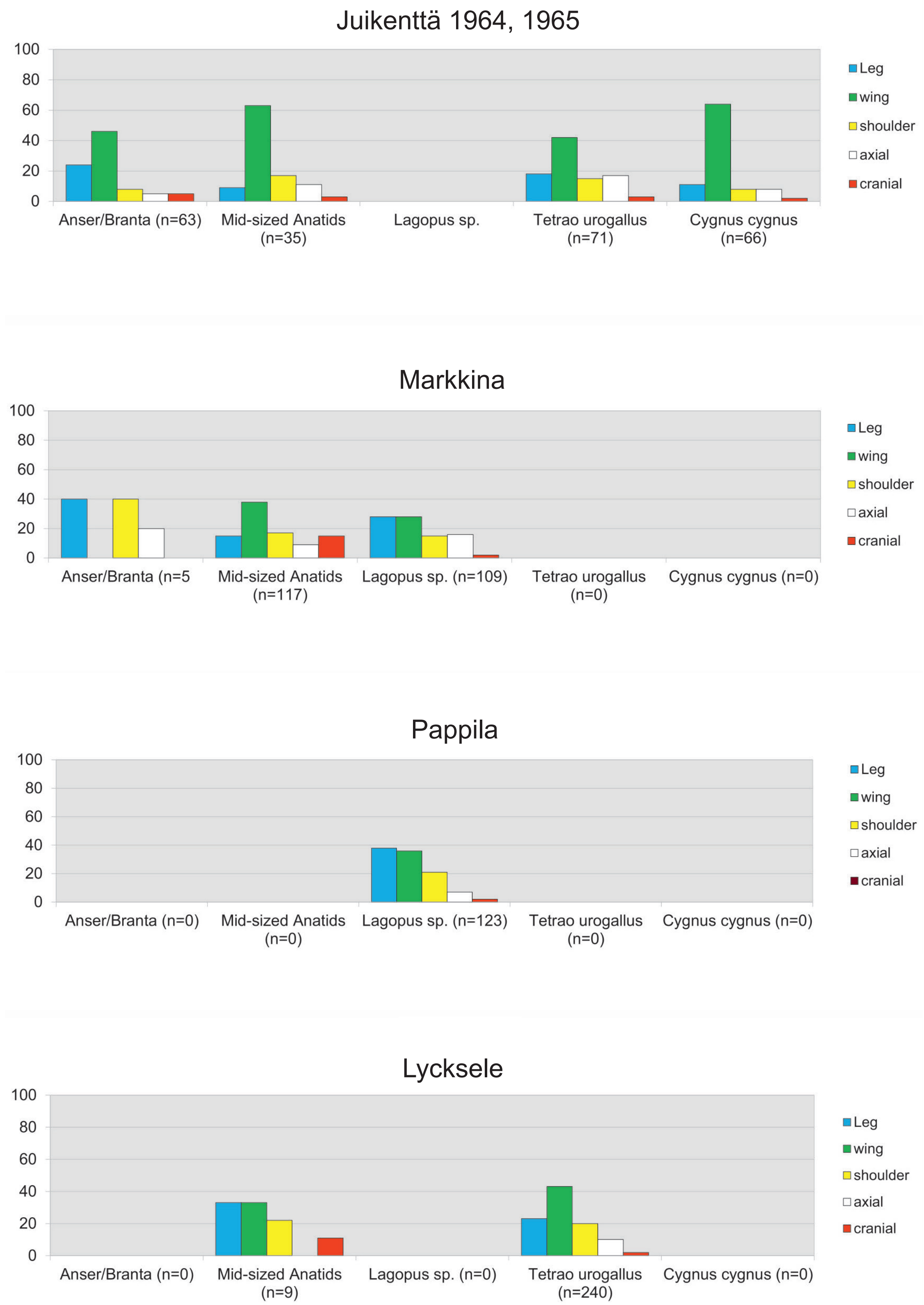

Figure 12. Anatomical distribution (in per cent) of the bird body elements at Juikenttä, Markkina, Pappila and Lycksele. Leg = femur, tibiotarsus, tarsometatarsus; wing = humerus, ulna, radius; shoulder = scapula, coracoid, furcula; axial = vertebrae, synsacrum, sternum; cranial= cranium, dentale, premaxillare, articulare.

also mention the presence of skull fragments and vertebrae as possible evidence of the utilization of tamed animals, whereas their absence could indicate initial butchering outside the camp, as would be expected if wild reindeer were hunted.

Unfortunately, the body size of the individual reindeer could not be estimated due to lack of osteometrical data. The astragali from Nukkumajoki 2 (KM 20278) are of all sizes, and their distribution probably indicates the slaughtering of individuals of both sexes rather than the presence of semi-domestic reindeer, as suggested by Magnell (2002). As to the age structure, based on teeth, young adults dominate at all sites, but juvenile reindeer are also present in all larger bone samples. Fragments of cranium (and vertebrae) have been identified at all sites. This is, however, very weak evidence for reindeer herding.

One distinctive feature in all bone samples in our study, except for those from cottage 2 at Markkina, is the scarcity of antlers. Antlers–in addition to skulls–have traditionally been the most used parts of the skeleton in sacrifices at ceremonial places and burials (Zachrisson 2009). These parts were sometimes taken to *sieidi* sites and graves (Harlin 2007; Harlin & Ojanlatva 2008; Äikäs et al. 2009; Mulk 2009) and therefore, are perhaps not abundant at settlement sites (see also Lahti 2006a). Antlers have also traditionally been important raw materials for producing other artefacts.

Animal husbandry

Cattle, sheep/goat and domestic pig were found only at the market places Markkina and Pappila and at the site Autiokenttä. The composition of the refuse fauna at Autiokenttä is very similar to that at Silbojokk, a 17th-century silver mining community in northern Sweden (Sten 1989). Sten (1989) has interpreted the relatively high number of bone fragments from domestic species as evidence of meat used by the miners, not by the Saami. Cattle, sheep, goats and domestic pigs would have required shelter and fodder in the winter, which the Saami at Silbojokk did not supply at all or only to a restricted extent. The same reasoning could be applied to Autiokenttä. This area was first used by the Saami, but Finnish settlers had replaced them completely by the middle of the 19th century (Itkonen 1948a: 96–7). The bones from domestic species could derive from the settler's households, and the reindeer bones could derive from those of the Saami. On the other hand, according to Itkonen (1948b: 191) the Saami started building stock houses and converted to animal husbandry in the middle of the 18th century, just after the reindeer plague. At Autiokenttä, one dwelling has been interpreted as a possible animal shelter, since it lacks a fire place (Honkanen 1982).

The presence of cattle bones at the market places Pappila and Markkina could be interpreted as an indication of meat transported by the merchants from Tornio and other towns. However, the distribution of the different skeletal elements, that is, the presence of fragments of the skull and mandible in the material, indicates that whole carcasses were handled at the site. In Utsjoki, the inhabitants along the river Teno are known to have kept cattle and sheep in the 18th century (Itkonen 1948b: 194). Sheep bones have also been found at Saami *sieidi* sites (e.g. Harlin 2007; Harlin & Ojanlatva 2008). One sheep bone was found at a sacrificial site on the island of Ukonsaari in Inari and has been dated to the 14th century (Okkonen 2007). In the 17th century, the reindeer herding Saami traded sheep and goats from the sea-based Saami and sometimes even butchered cattle (Hansen 2005: 177 and references within).

The distribution of the elements of sheep/goat is quite different from that of cattle; the sheep/goat bones found at the sites come almost entirely from meaty parts of the carcass. This may indicate that salted or smoked joints of sheep or goat were carried by traders. This is somewhat strange, since sheep or goats would have been much easier to take along to markets than cattle, and they also need less shelter and food. These were crucial factors, since both markets were held during the mid-winter. At Lycksele, only some fragments of sheep/goat have been identified (Zachrisson 1976: 83). According to Hambleton & Rowley-Conwy (1997) the predominant mode of subsistence at the medieval site Cæccevaj'njar', North Norway, was based on wild reindeer hunting and supplemented by sheep, seals, small mammals, birds, fish and whales. Here, the presence of sheep bones is suggested to represent milking animals, indicating that reindeer milking had been replaced by that of sheep.

Fur trade

Fur trade is known to have played a significant role in northern Fennoscandia, especially during the Iron Age and the Middle Ages (Mulk 1994 and references within). This led to the accumulation of wealth, which in turn, could be used for religious purposes, that is, as offerings (Carpelan 1992; Mulk 1994). Hunting fur-bearing animals, except for beavers, was traditionally an individual activity, whereas reindeer and beaver were hunted collectively (Carpelan 1991). Both hunting and the fur trade were concentrated in winter villages (Carpelan 1992; Mulk 1994).

Bones from fur-bearing animals are rare in all studied samples. The same phenomenon is seen in Lycksele and Silbojokk in Sweden (Ekman & Iregren 1984; Sten 1989). At the winter village of Nukkumajoki, only one mandible of a wolverine and one tibia of a pine marten were found, as well as some beaver bones. This is even less than in the summer village of Juikenttä. The material from Autiokenttä included one fragment of an ulna of a brown bear and some red fox bones. The only evidence of fur animals at the winter markets are the few red/Arctic fox and squirrel bones from Markkina, as well as one wolf bone, one beaver bone and two Arctic hare bones from Pappila. If furs were traded here, they were not prepared at the site but were brought to the market as finished products.

It is obvious that carnivores and other fur-bearing animals were not skinned and prepared at the sites or market places, but probably where they were caught.

A potential indication of the ritual use of animals in the excavated material is the nearly total absence of bear bones. This absence could be explained by the fact that the bear is a sacred animal for the Saami, and for that reason, bear carcasses and bones were treated and deposited in a special way (and were not deposited in villages and market places) (Myrstad 1996; Bäckman 2000; Edbom 2000).

Fowling

The bird sample from Juikenttä is large and represents the intensive use of bird resources in the area. The sample from Markkina is also large, but the number of identified species is clearly lower. The species diversity and the amount of bird bones are low at all other sites.

Here, it is important to note that the bird bones from Markkina have not been re-analyzed for this study. In the material from Markkina, 96 bones are from anatid birds, and 74 bones are from other birds that have not been identified by species. We cannot really compare these samples without a thorough osteological analysis. Furthermore, the sample size and excavation methods are significant factors affecting the composition of archaeological bone assemblages. Depending on the accuracy of sample recovery (mainly sieving and mesh-size), bones from small animals can be totally lost. It has also been shown by previous studies that taxonomic diversity rises with increased sample size (e.g. Mannermaa 2004; Ukkonen 2004).

In general, the species distributions at our study sites clearly reflect the seasons of use of the sites. The summer occupation site Juikenttä has a variety of local and migratory bird species, and the winter villages and winter market places have mainly local species. Markkina is an exception, such that both local *Lagopus* birds and anatid birds are numerous.

Almost exclusively bones of local bird species were identified in Nukkumajoki, Autiokenttä and Pappila (the only exception being two migratory anatid bones from Pappila). It is obvious that the main reason for the low species diversity and scarcity of bird bones in Nukkumajoki is that this site was used during the winter-time when most of the migratory birds are absent. Relative to the other sites, Pappila and Markkina, the two winter market places, have many *Lagopus* bones, and these materials also have similar anatomical distributions within this bird group, indicating that complete birds were handled at these sites. The abundance of the *Lagopus*-birds at the winter markets is not surprising as these birds were mainly hunted in the winter with traps and snares and were very valuable items to sell during the winter (Fellman 1907; Itkonen 1948b: 43–4). Interestingly, mid-sized anatids are more common than the *Lagopus*-birds in Markkina. Additionally, geese are present, indicating occupation of this site during the season when migratory birds were available.

In contrast to the market places of Pappila and Markkina, the genus *Lagopus* is scarce at Juikenttä and totally lacking at Autiokenttä and Nukkumajoki. This is interesting in the light of the importance of this genus and especially that of the willow grouse for the people living in Lapland during the 19th and 20th centuries (Itkonen 1948b: 7) during which willow grouse was the most important game bird in Lapland, and the capercaillie the second. This discrepancy may be explained by the differences in the season of occupation of the sites and by the fact that willow grouse was not always considered to be a delicacy among the Saami (Fellman 1906: 440, 491). On the other hand, grouse feathers were a sellable item, which explains the presence of bird bones at the market places (Itkonen 1948a: 44). In Norway, during the 17th century, reindeer herding Saami paid their taxes to the crown in the form of reindeer fur related products, such as fur boots and mittens, but also with feathers (Hansen 2005: 176).

The bird species identified and the presence of bones from young swans and geese at Juikenttä clearly indicates the use of the site in the spring, summer and early autumn (most migratory species arrive to Lapland for breeding time in summer and leave for their wintering areas after breeding). Use during the summer season also explains the high number of bird bones and identified species. Itkonen (1948b: 32) reports that water birds (in particular, geese) were so important for the Skolt Saami people that moving from the winter villages to the summer villages was done just before their arrival.

Apart from the very small number of bones from the genus *Lagopus*, the taxonomic distribution of the birds in the materials from Markkina and Juikenttä somewhat resemble the bird material obtained from the 17th-century early-modern town of Tornio (Southern Lapland). Here, the *Lagopus* species and capercaillie are very common, followed by swans and geese (Puputti 2009). Some similarities can be seen in the distribution of species at Juikenttä and Lycksele. However, one clear difference is the abundance of the whooper swans and geese at Juikenttä and the absence of these bird groups in Lycksele (Zachrisson 1976; Ekman & Iregren 1984).

Capercaillie are present at some sites but totally absent at others, and black grouse is present only at Juikenttä. We could explain that the differences in the abundances of these large grouse-species are due to the season of the use of the site and that these forest birds may not have been very common in all parts of Lapland. On the other hand, capercaillie bones are commonly found in *sieidi* sites (e.g. Harlin 2007; Harlin & Ojanlatva 2008). Along with capercaillies also whooper swans seem to be the typical bird species found at sacrificial sites (Harlin 2007; Okkonen 2007; Harlin & Ojanlatva 2008; Mulk 2009; Äikäs et al. 2009). Both are abundant at Juikenttä and at the sacrificial site at Viddjavárri in northern Sweden (1000–1100 AD; Mulk 2009).

The occasional finds of crane (*Grus grus*), the great cormorant (*Phalacrocorax carbo*) and the Northern goshawk (*Accipiter gentilis*) at Juikenttä might have been consumed or they may have had some other uses. Based on ethnographic sources, the attitude towards eating cranes varies among the Saami of different areas (Itkonen 1948b: 36, 370; Paulaharju 1961: 118–9), and even hawks were eaten at times. Also divers were sometimes eaten (Itkonen 1948a: 507; Itkonen 1948b: 50), but perhaps more importantly, their skins and feathers were used in the making of bags and pouches (e.g. Kielatis 2000). All bird species identified at Juikenttä might have been locally hunted. The great cormorant may have lived near the Arctic Ocean, or it may be one of the great cormorants occasionally observed inland (BirdLife at https://www.tiira.fi/ mentions 106 observations of cormorants in Lapland during the period 1.1.2016–31.12.2016).

The distribution of skeletal elements at the two largest sample sites (Juikenttä and Markkina) can be used to interpret the bird carcass treatment at these sites. At Juikenttä, a scarcity of scapulae is evident. Otherwise, the relatively even anatomical distribution of the various parts of the skeletons of all bird groups indicates the deposition of complete birds at these sites.

Fishing

Based on the available refuse fauna, it is difficult to estimate the importance of fishing for the livelihoods of the Saami. All sites are situated near rivers and lakes, and it can be assumed that fish were caught and consumed as they are today. Salmonid fish were an important economic resource, as indicated by the material from the Pappila market place in Utsjoki, near the River Teno. Cod bones at both market places (Pappila and Markkina) probably derive from dried fish, since there are practically no elements from the head regions of cod skeletons among the refuse. The fish may have been brought to the market place for sale or as provisions. The importance of dried fish for the expansion of Sweden has also been emphasized by Itkonen (1948b: 248). According to Fellman (1907), however, half of the salmon caught in the River Teno was eaten by the Saami themselves.

Conclusions

Our material derives from winter market places and winter and summer villages in Finnish Lapland. In general, reindeer (wild or semi-domestic) remains dominate the excavated materials, which is a typical feature of many Saami sites. The species distributions are strongly affected by the seasonality of the sites; the sites used in the summer have a larger variety of species than the sites that were used during the winter. This pattern in bone materials is typical for samples from Saami societies, whose way of life is characterized by seasonal activities and movements.

The anatomic distribution of the reindeer bones indicates a highly economical use of the carcasses, especially the utilization of bone marrow by splitting the bones. It is not possible to use this material to infer whether the utilized reindeer were semi-domestic or wild. In addition to reindeer hunting and herding, animal husbandry was part of the livelihood of medieval to early modern Saami, albeit on a smaller scale.

The low number of fur animal bones at our study sites is somewhat surprising since hunting for, using and selling furs are known to have been practised by the Saami, according to ethnographic literature. Winter market places were the typical places to sell fur and feather items. Based on the material found at the market sites, these resources were not prepared on site but were brought to the market as final products.

Fowling, especially the snaring of tetraonid birds, was an important part of the Saami livelihood. Birds seem to have been brought to the sites and utilized as complete carcasses. Fish are found at all sites. The scarcity of the identified salmonid fish may be an artefact, since vertebrae were not always identified by species. At both market places, dried cod was utilized and was certainly also sold.

One indication of rituals could be the scarcity of antlers in the studied bone assemblages. In some cases these elements have been deposited to a sacred site and therefore they are not present in a settlements. However, antlers were also used as raw materials to produce artefacts, so the lack of antlers can not self-evidently refer to sacrifices.

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Globalization and tradition in Forest Sámi commemoration rituals

Textiles and animal skins in the 17th-century burial ground in Mukkala, eastern Lapland, Finland

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Abstract

The Mukkala burial ground consists of eight excavated inhumation burials that all date to the middle of the 17th century and 1–2 near-by shaman burials from the beginning of the century. The site was excavated by Jorma Leppäaho in the 1930s. Since its discovery, Mukkala is of importance as one of the few excavated Sámi burial grounds and the only one representing the later extinct Forest Sámi population in Finland.

The aim of this paper is to reveal the quality of the Forest Sámi culture of the Sompio Lapp village, when the cultural assimilation into the neighbouring populations was already under way. The paper concentrates on the organic material excavated in Mukkala, the burial ground of the Sompio Lapp village. First, we present the textiles which were made for everyday use by weaving, knitting, naalebinding (nål(e)binding, one needle knitting), and braiding. Second, we study the remains of animal skins, which were used for wrapping the deceased and for fur shoes and pouches. Finally, we recognize both the continuity of age-old circumpolar traditions, novelties in local production and dyeing of textiles, and the acquiring of commodities by trade.

Keywords: Forest Sámi, textiles, animal hair identification, 17th century

Introduction

The Mukkala burial ground is situated in eastern Lapland (Finland) in Savukoski which, in the 17th century, belonged to the Sompio Lapp village (Figure 1). In 1934, Jorma Leppäaho (1937) excavated this burial ground with its nearby open-air burial of a possible shaman. Based on the coin finds, he dated the burial ground to the 1650s and the potential shaman burial to the beginning of the 17th century. As the number of identified Sámi burials from the medieval and early-modern period is low (Storå 1971: 86, 116; Purhonen 1995; Svestad 2007), Mukkala is of importance among the few excavated sites.

The identity of those buried in Mukkala has been regarded as the so-called Forest Sámi, i.e., groups which lived in the boreal forest zone mainly surviving on hunting, fishing, and foraging. The term was used in the 16th to 18th centuries especially for the groups living in the modern Savukoski region (Itkonen 1948a:122; Kulonen et al. [eds] 2005: 124; Storå 1971: 36–60; cf. Hansen & Olsen 2006: 192–5). The colonization of the area gradually led to the assimilation of the Sámi into the groups of Finns and to the adaptation of peasant life. In addition, the local Kemi Sámi language assimilated into the Finnish language and disappeared by the end of the 19th century (Itkonen 1948a: 96–7, 116–7, 122).

In Mukkala, the burial customs and the grave goods reflect an early stage of the assimilation process. The emergence of Christian symbols like the iron burial crosses and a signet ring featuring the Crucifixion (Immonen 2015: 362, 373) has been interpreted as evidence of either the ongoing Christianization of the Sámi population (Itkonen 1948b: 350–1; Storå 1971: 94; Elo & Seppälä 2012:

Figure 1. The location of the Mukkala burial ground and the modern distribution of Sámi languages (from Kulonen et al. 2005), dark area. The first official parishes in Finnish Lapland, Kemi and Tornio, were established in the 14th century, the churches of Inari and Kemijärvi were built in the mid-17th century, and the Russian Orthodox monastery in Kandalaksha was built in the 16th century. Drawing: T. Kirkinen.

36), or the trade contacts with surrounding Christian groups (Svestad 2007: 48–9). The nearest and most obvious zone of contact was the area around Lake Kemijärvi, 90 kilometers south of Mukkala. The colonization of the area was begun in the late 16th century by Finnish peasants. The first church was built in Kemijärvi in 1647 and was used as a base from which the conversion of the Sámi in eastern Lapland was carried out (Itkonen 1948a: 64–7, 112). See Figure 1.

The 17th-century colonial activity in northern Fennoscandia was highly motivated by trade and by the policies of Sweden and Denmark-Norway, which tended to take control over resources, i.e., furs, fish, metals, and pearls. In eastern Lapland, the Sámi were also in contact with fur trading companies, which especially exported beaver skins to the Russian markets (Itkonen 1944; Storå 1971: 54–60; Hansen & Olsen 2006: 229–61; Nordin 2010: 58). The interest in northern furs was based not only on their high quality, but also on the fact that, in the more southern areas, the local populations of game had already suffered from extensive overhunting (Pylkkänen 1956: 86–103; see also Kulonen et al. [eds] 2005: 382).

In the 17th century, the desire for fashionable status items and foreign consumer goods was on the rise. In Mukkala's find material, the influence of colonial world trade can be read in many ways, for example in the discovery of a clay tobacco pipe (SU5187:11, the Finno-Ugric collection at the National Museum of Finland) and in Christian motifs. According to historical sources, the items traded in the Sámi area consisted of fabrics, hemp, linen, yarn, rope, pelts, mittens, iron, kettles, knives, nails, spear heads, coins, bronze, and silver items, groceries and alcohol (Itkonen 1944, 1948a: 37, 40, 43). Many of these items, especially metal artefacts like knives, silver jewellery, and coffin nails exist among the finds in Mukkala. Most interestingly, Mukkala's deceased were accompanied by a versatile textile and skin material, i.e., by fabrics, accessories made by knitting and naalebinding, ribbons, fur and textile pouches, Sámi fur shoes and animal skins used for wrapping (see Leppäaho 1937).

In this paper, we present an analysis of the textile and skin finds from Mukkala. We aim to produce new knowledge about the ways in which cloth-type materials reflect the 17th-century Forest Sámi material culture at the intersection of the traditional circumpolar way of life and the pre-modern, colonial world. Our focus is on the elements traditionally regarded as Sámi, i.e., Sámi fur shoes, ribbons, and the skins used for wrapping, as well as the materials used for traditional dyeing. Although the study material is fragmentary by nature and, e.g., all skin items were not salvaged during the excavation, we regard the existing material as sufficient for our study.

Mukkala burial ground and open-air burial(s)

The Mukkala site, named after the Mukkala farmstead, is situated near the Luirojoki River in Savukoski parish, eastern Lapland (Figure 1). The site (Figure 2) was discovered in 1931 when a local forest officer sent an assemblage of items to the National Museum of Finland. The finds (SU5125), among them bronze rings, coins used as pendants, finger rings, and arrow heads were found on the chest of a skeleton, covered only by a thin layer of moss. Most of all the bronze rings and finger rings have been regarded as the pointers of a Sámi drum. Consequently, the find has been interpreted as an open-air Sámi shaman burial, accompanied with a "hoard" (Leppäaho 1937; for shaman burials see Kopisto 1971; Harjula 2006; Piha 2011: 47–51; Purhonen 1995). Later on, Christian Carpelan (1964) surveyed the site in the 1960s and heard from the locals that another open-air burial was found at Mukkala at the end of the 1930s. Unfortunately, the finds of that burial, i.e., pieces of copper plate and a metal item, were discarded.

The Mukkala burial ground is situated about 50 meters ESE from the shaman burial. It was partly destroyed by ditch digging and farming, as human bones were reported to have been found there through the years (Leppäaho 1937; Carpelan 1964; Elo & Seppälä 2012: 36). In 1934, Jorma Leppäaho excavated eight graves there, i.e., four or five male, two or three female, and one child burial. Most probably, this was only part of the total number of graves at the burial ground; in the 1960s, C. Carpelan (1964) recovered traces of unexcavated and partly destroyed burials, some of which were threatened by modern land use.

Figure 2. The Mukkala site in the 1930s. Photo: J. Leppäaho, National Museum of Finland.

The excavated graves were oriented toward N–S, NE–SW or NW–SE, and only one of them (grave V) presented the tentatively Christian orientation of E–W. The graves were 40–80 cm in depth. In six of them the deceased was buried in a coffin or a coffin-like wooden structure, three of which were sparsely joint with nails (see also Storå 1971: 174). Two bodies, a child (grave VI) and a female (grave IV; see Figure 3), were only wrapped in a skin. Additionally, graves II, III, and V were marked with iron burial crosses. The grave goods were relatively few and consisted mainly of fire steels, knives, finger rings, and pouches (in graves III, IV, and VIII). The male burial in grave V was interpreted as a shaman burial as its find material correlates well with the one found in 1931. In graves I, II, VI, and VII no personal items were found (Leppäaho 1937).

Material and methods

Textiles

Textile accessories and their fragments were preserved in the Mukkala graves. Most of them have never been cleaned, which restricted their handling and documenting. The most remarkable accessories, the woolen ribbons from grave I, are still wrapped around the shafts of the fur shoes (SU5187:4a and SU5187:4b, Figure 4). Additionally, mineralized traces of textiles have remained on surfaces of the iron grave goods. The textiles and pseudomorphs were examined with a stereomicroscope and digital photo enlargements in order to document the direction of twist and ply of the yarns and the thread count. The fiber material of the braids was analysis with a transmitted light microscope.

Two samples were taken from the ribbons (SU5187:4) in the grave I and sent to the textile laboratory of KIK-IRPA, Brussels, Belgium for dye analysis. The investigation of organic dye compounds has been performed with high performance liquid chromatography and photo-diode array detection. Prior to this, dye extraction was obtained in a strong acidic environment using a mixture of 37% hydrochloric acid, methanol and water with purification of the extracts with ethyl acetate. Secondly also a milder acidic method

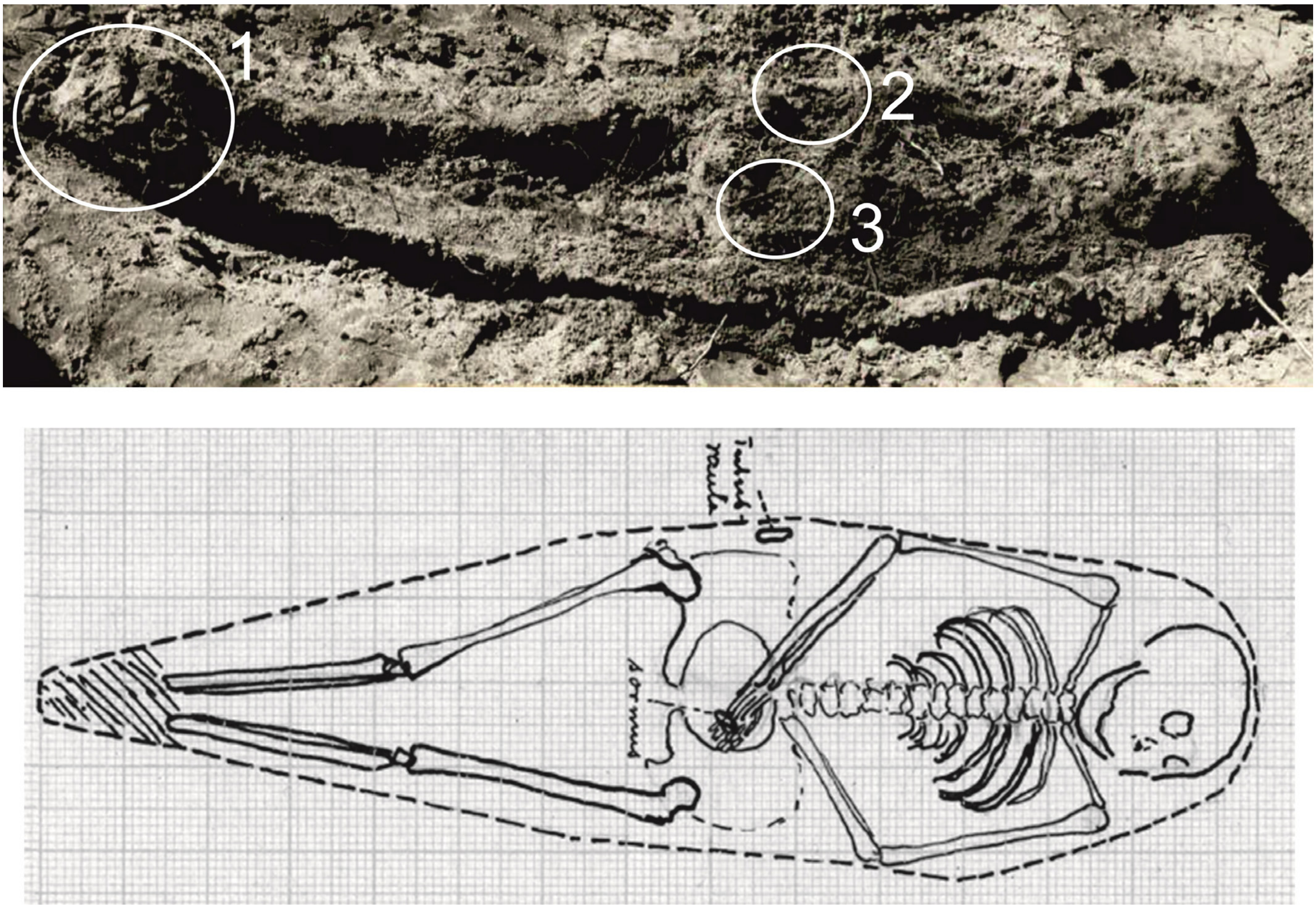

Figure 3. The female in grave IV was wrapped in an animal skin and furnished with 1) fur shoes, 2) a fire steel, a knife, and a 3) finger ring. Photo and drawing: J. Leppäaho, National Museum of Finland.

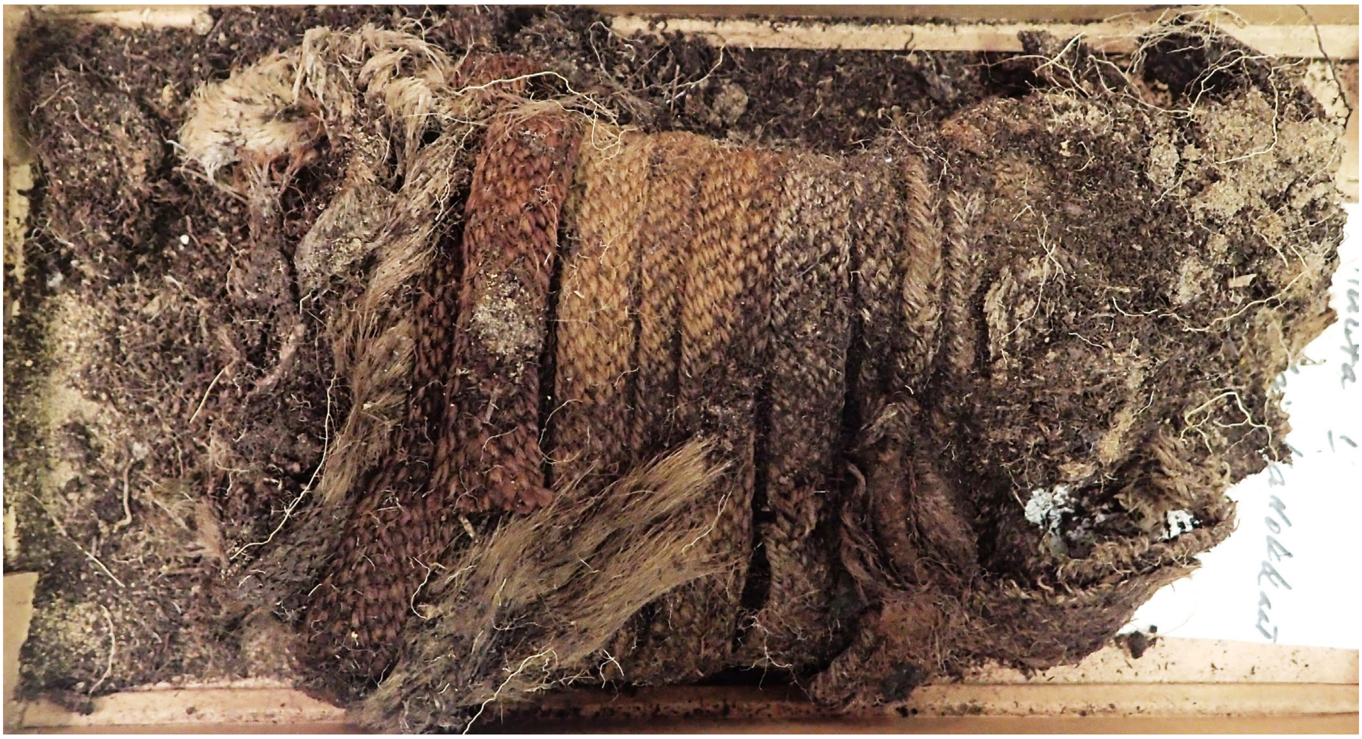

Figure 4. The three colored ribbons in grave I are still wrapped around the shafts of the fur shoes. The combined size of the fur shoe and ribbon ensemble is 195 x 105 x 40 mm (SU5187:4a) and 220 x 100 x 55 mm (SU5187:4b). Photo: A. Arponen.

was followed using a 2.1M oxalic acid, acetone, methanol and water mixture, all according to earlier described protocols by Vanden Berghe (Vanden Berghe et al. 2009). Scanning electron microscopy with energy dispersive X-ray detection (Zeiss EVO 150 with detector from Oxford Instruments) was used further on to identify the presence of possible inorganic substances related to the red coloration. For this, the conduction of the samples was first improved by a thin carbon layer coating.

Animal skins and furs

Animal skins have been used in the Mukkala graves both for wrapping the deceased and for fur shoes and pouches. The items were relatively well preserved, but from the wrappings only loose hairs were left for the study. The remains of skins were identified by species through the morphological study of the hairs.

Each investigated sample consisted of 4–10 hairs or hair fragments. As a result, a total of 18 samples were prepared for optical microscopic examination by mounting them in Entellan Neo after Greaves & Saville (1995: 7). Additionally, the scale structures were studied by preparing longitudinal negative casts with transparent nail polish (after Kirk et al. 1949; Tridico et al. 2014: 3). The cross sections of the fibers were made after Greaves & Saville (1995: 39–40). The research material is presented in Appendix 1. The key features of the identification process were the diameter, length, and cross section of the hair, the shape of the root section, the structure of the medulla and cuticular scales, the width of the cortex, the presence of pigment granules, and the overall coloring of the hair (See Goodway 1987). The identification of fibers was based on the identification keys in Appleyard (1978), Rast-Eicher (2016) and Teerink (2003). Additionally, the reference material collected at the Finnish Museum of Natural History, University of Helsinki, was vital for the identification.

Also, the animal-skin string accompanied by a bronze chain (SU5187:42) in the shaman's grave (grave V) was studied but it did not contain any morphological features for identification.

Results

Ribbons

The most remarkable textiles in the Mukkala assemblage is the pair of woolen ribbons in grave I. They are wrapped approximately eight times around the shaft of the fur shoes (SU5187:4a and SU5187:4b). The length of the nearly identical ribbons is approximately two meters each. They were made by way of sewing together three stumps of braids one after another. The width of the braids is 12–14 mm and they are of three colors, i.e., brownish red, brownish yellow, and white. In both ribbons, the brownish-yellow braid is in the middle. The z-twisted yarns have been woven into braids by finger loop braiding, i.e., without the help of any equipment. There have probably been eight loops in each of the braids (Figure 5). At the brownish-red end of the ribbon SU5187:4a, there is a knot and, at the white end, the braid is divided into two plaited tails, which are approximately 5 mm wide. Near the point of division, the flat part of the braid is decorated by sewing red and blue squares and circles of woolen cloth onto it. Regarding the ribbon SU5187:4b, the brownish-red end shifts from being flat to that of a semi-circle that is knotted.

The dye analyses of the dark red and brownish orange braid fibers (Figure 6) result twice in the detection of degradation compounds of tannins, such as caffeic, protocatechuic, gallic, ellagic and ferrulic acid and other colorless derivatives. Other detected constituents were benzoic acid derivatives (paramethoxy and parahydroxy benzoic acids) indicative for fiber degradation, as well as an unknown flavonoid constituent, more likely referring to contamination from the burial ground than related to dyeing. Element analysis further on resulted in the detection of some iron and a high amount of sulphur on both sample surfaces, which refers to the presence of iron sulphides or sulphates on the fibers rather than to the use of a red inorganic pigment.

Textiles made by knitting and naalebinding

The catalogue number SU5187:4b includes a fragment of knitted sock and in the same grave (grave I) also other fragments of knitted textile (SU5187:5, Figure 6) were preserved. Their oblong shape points toward the shaft of a sock. In grave V (the shaman's grave) some fragments of a textile made by naalebinding (SU5187:50, Figure 7) were found. They are probably parts of a mitten, but possibility of a hat cannot be ruled out. The yarns of the textiles mentioned in this connection are s-twisted and undyed. The yellowish or brownish color is due to the burial conditions.

A piece of fabric and pseudomorphs: traces of clothes and accessories

In the graves with iron grave goods there are mineralized fabrics, pseudomorphs, indicating the presence of clothes and accessories (Figure 8). There are 11–19 z-twisted yarns / cm in the pseudomorphs of the plain weave fabrics. There is no remarkable difference in the number of ends and picks / cm. Only one tiny piece of cloth (SU5187:15) has been preserved as non-mineralized. The undyed plain weave fabric with z-twisted yarns is in contact with a piece of fur found in grave III. It was situated next to the shoulder of the deceased.

Fur shoes

According to Leppäaho, the remains of fur shoes were observed in all graves (e.g. see Figure 3), although items themselves (SU5187:4, :4a and :4b, possibly also :5) were archived only from grave I in which the shoes were tied up with ribbons (Figure 4). Moreover, although Leppäaho wrote in the catalogue that the shoes were used with the hairy side inside, it is evident that the hairy side was outside.

The analyzed guard hairs had a broad lattice medulla with mosaic-like cuticular scales, which are typical features of *Cervidae* sp. hairs (Appleyard 1978; Rast-Eicher 2016: 228–9, 235–6). Notably, the hairs had a clear cortex and a straight root section that separate them from the body hairs of an elk or a reindeer. Instead, they have the best match with reference samples collected from elk's feet and head (Appendix 1).

Skins for wrapping the deceased

Animal skins were used in Mukkala for wrapping or as shrouds in five burials, i.e., in graves III, IV (Figure 3), V, VI, and VIII. Leppäaho collected hair samples (SU5187:14, :15, :50, :51/:53, :55) from three graves. The hairs were identified as reindeer (*Rangifer tarandus;* graves V and VIII) and brown bear (*Ursus arctos*; grave III) hairs (Appendix 1).

Pouches

The remains of a pouch with fire-making equipment (SU5187:12, :13, :14) were found in grave III. The accompanied hairs were identified as *Mustelidae* sp. or red fox (*Vulpes vulpes*) fur (Appendix 1). The skin pouch from grave V (SU5187:45) was unfortunately not available

Figure 5. The woolen braids have been made by means of finger loop braiding. For the ribbons, the stubs of braids have been sewn together one after another. The width of the braids is 12–14 mm. Photo: A. Arponen.

Figure 6. Fragments of a knitted textile, most probably a shaft of a sock. Grave I. Photo: A. Arponen

Figure 7. Fragments of a textile, probably a mitten, made by naalebinding. Grave V. Photo: A. Arponen.

Figure 8. A close view of a mineralized fabric, a pseudomorph, on the surface of a corroded fire steel. Next to the pseudomorph two pieces of flint and quartzite. Grave V. Photo: A. Arponen.

for the study. On the mineralized textile and fur layers on the surface of the iron fire-making equipment, it can be hypothesized that the pouch (SU5187:51) from grave VIII was made of woven textile. Moreover, the deer hairs which were on the top of the corrosion crust originated either from clothing or from the skin used for wrapping.

Discussion

Ethnographic parallels for cloth-type material

In Mukkala, the scarcity of find material, as well as the excavation and documentation method, do not provide much room for making specific conclusions about the way the dead were clothed. Therefore, we have applied ethnographical comparisons in presenting hypotheses about the way the deceased were equipped.

The piece of a plain weave cloth and pseudomorphs in some of the burials indicate the use of clothes and / or accessories. The metal items do not provide any additional information about the clothes, as there were no dress fasteners like buttons, hooks, or brooches. In the possible shaman grave (grave V), a buckle (SU5187:27) possibly from a belt and two brooch fragments (SU5187:25, 26) were found, but they have been interpreted as pointers or remains of a Sámi drum in previous research literature (Leppäaho 1937; Itkonen 1948b: 350; Purhonen 1995).

According to ethnographical sources, a deceased Sámi was clothed either in his/her everyday clothes, best clothes, wedding clothes or in garments he/she was wearing at the time of death. Sometimes a naked corpse was wrapped in linen cloths, and sometimes the clothes were collected on top of the grave or discarded (Itkonen 1948b: 352–3, 355; Manker 1961: 189–90; Storå 1971: 213–4, 225). Hence, it is possible that the pseudomorphs indicate the use of shirts (e.g., Itkonen 1948a: 352) or wrappings made of plant fibers. Moreover, the piling of textiles on the grave might explain the concentration of finds on the chest of the deceased in the open-air shaman burial. In this case the metal rings, coins, and bear teeth might refer to ornaments that were bound to clothes (Ervasti 1956: 15; Schefferus 1956: 234, 237–9).

In the ethnographical sources, the importance of equipping the deceased with mittens and especially with socks and shoes for the after-life journey has been pointed out (Harva 1948: 489; Itkonen 1948b: 353, 355; Manker 1961: 189; Storå 1971: 213). In Mukkala, the remains of socks and a possible mitten as well as fur shoes verify this custom. In grave I, the fur for the shoes originated from elk leg or head skin. According to N. Storå (1971: 213) and Itkonen (1948a: 323–6), fur shoes in eastern Lapland were made of the elk-leg skins, not only of reindeer-leg or -head skins.

In the research literature, the wrapping of bodies in reindeer skins or in birch bark has been connected closely to Sámi ethnicity, as these materials have been found in the excavated Sámi burial grounds and reported in historical and ethnographical sources (Waronen 1898: 64–5; Itkonen 1948a: 350; Manker 1961: 176–9, 190–2; Storå 1971: 87, 92, 95–6, 106; Zachrisson 1997; DuBois 1999: 71; Svestad 2007; 2011).

In Mukkala, the remains of reindeer or bear hairs, which were discovered from five of the eight burials have been interpreted as remains of wrappings or hides with which the coffin was lined. No remains of birch bark were reported from the graves.

However, the use of deer and bear skins for wrapping the dead cannot be identified solely as a Sámi habit. Instead, it was a widespread and long-lasting northern tradition, the practice of which continued from the Mesolithic Stone Age up until the 19th century (Waronen 1898: 65; Harva 1933: 206, 209; Osgood 1936/1970:145; Itkonen 1948b: 353–4; Storå 1971: 92–3, 95; Albrethsen & Petersen 1975; Albrethsen et al. 1976; Larsson 1988a; 1988b; Petersen et al. 1993; Petersen & Nielsen 1993; Pritzker 2000; Nilsson Stutz 2006: 218, 231-2; Liesowska 2015; Jonuks 2016). Most interesting were the wrapping of bodies in reindeer and elk skins, birch bark, and occasionally in cattle and bear skins. This was a common phenomenon also in the southern Finnish Late Iron Age and medieval period inhumation burials (Kirkinen 2015).

Globalization in action

The acquiring of cloth-type materials in the 17th-century Sompio Lapp village was a multifaceted act, which is documented in tax records and historical sources. In general, the livelihood of the local Forest Sámi people required annual migration from one place to another, which did not allow raising sheep or growing plants in order to acquire fiber material for *fabrics* (Itkonen 1948b: 183–4). As a result, wool and plant fibers (especially hemp and linen) were obtained as yarns or as cloths through trade. Merchants traveling from one Lapp village to another exchanged them with furs, the day's catch, and other produce of nature (Itkonen 1944: 12–3 note 4). In the beginning of the 17th century, Sompio was also visited by tax collectors representing the sovereigns of Sweden, Denmark-Norway, and Russia (Itkonen 1944: 34, 36, 91). Along with the merchants and tax collectors, quality fabrics reached the remote areas of northern Scandinavia including Sompio. From the beginning of the 16th century, a versatile collection of Dutch, Flemish, Silesian, Bohemian, and English, and later also Russian and Swedish fabrics were traded among the Sámi of Lapland (Itkonen 1944: 11 note 1, 19). Peasants and Sea Sámi, whose more sedentary life allowed sheep raising and weaving with a loom, could offer coarser cloths and accessories (for the keeping of sheep, see Itkonen 1948b: 189, note 8).

Besides imported items, there was evidence of local textile production at Mukkala. *The ribbons* which were found from grave I represent textiles that were manufactured and sold by the Sámi at the latest in the early 17th century (Itkonen 1944: 114). The Sámi have traditionally used ribbons to fasten coats, dresses and fur shoes (Itkonen 1948a: 358–61). Of the many techniques to manufacture ribbons, even the most advanced one of weaving with rigid heddles, was adopted by the Sámi in the 17th century (Gjessing 1938: 50; Itkonen 1944: 114; Schefferus 1956: 286–7; Løvlid 2010: 15–8).

Based on the finds, the 17th-century Sompio Sámi knew two ways of manufacturing ribbons. The bone tablets found at their dwelling site in Juikenttä, Sodankylä indicate tablet weaving (Carpelan 1974: 59). With tablets, it would have been possible to manufacture long colorful bands with patterns. The ribbons in Mukkala grave I, however, were made by sewing together stumps of monochrome unpatterned braids made by the finger-loop technique. The Mukkala ribbons seem to be almost unique in the Sámi area. In the beginning of the 20th century, a couple of unpatterned ribbons (SU4904:7) from the Skolt Sámi area were deposited in the collection of the National Museum of Finland. In general, the Skolt Sámi have favored finger weaving in ribbon manufacturing, but these ribbons are made by using finger-loop braiding. Do these ribbons represent a retreating braiding technique in the Skolt Sámi – Sompio Lapp village area? Does the technique indicate a connection between the two areas? The material is too limited to answer the question definitively, but it has been hypothesized that part of the population in Savukoski parish has spoken the Skolt Sámi language[1] (Sammallahti 2015: 56).

In the literature depicting the way of life of the Sámi in the 18th, 19th, and early 20th century the plant species used in textile dyeing and tanning have been mentioned with varying accuracy (see, for instance, Fellman 1906; Sjögren 1828; Itkonen 1948a; Leem 1975; Linné 1971, 1977, 1986, 1991; Arponen 1998). As sources of yellow dye *Diphasiastrum ssp*. (species of clubmoss), flowers of *Galium verum* and leaves of *Betula ssp.* are mentioned. With roots of *Galium ssp*. and *Potentilla erecta* red and with *Parmelia saxatilis* (lichen) more brownish red was obtained. Bark of *Alnus ssp.* gave brown and black colors. Other plant species mentioned without indication of the obtained color are *Calluna vulgaris*, *Xanthoria candelaria* (lichen), *Galium boreale* (flowers), *Juniperus communis* (ruffles), *Rumex acetosa* (roots) and *Arctostaphylos uva-ursi* (twigs).

The Sámi used three wood species for tanning. They are *Salix ssp., Alnus ssp.* and *Betula ssp.* In different areas different species were favored. Additionally, the type of leather to be manufactured required a particular species of wood. The brown color of sisna leather could be changed into red by dyeing it with *Alnus ssp.* bark (Itkonen 1948a: 315–9).

The tannin related molecules detected in the red and the brownish-yellow braid yarns in the absence of any other organic red mordant dye or any inorganic red pigment, suggests the use of tannins (Cardon 2007: 409). Although a wide range of local and non-local plants exist which are rich in tannin, this could confirm the use of *Potentilla erecta*, eventually in combination with other tannin source(s). The fact that much more of these molecules were found in the red compared to the brownish-yellow fibers, might explain the difference in shade between the two. Mordanting and/or dyeing of textiles with tannins is a very old practice in northern Europe. Earliest evidence goes back to the Scandinavian Iron Age (Walton Rogers 1988; Vanden Berghe et al. 2009) and tannin, particularly in yarns with red shade, was recently encountered in textiles from a Danish first century AD grave (Vanden Berghe et al., forthcoming).

The knitted and naalebinded textiles from grave I most probably indicate local peasant production. Knitting and naalebinding are both techniques, which were used to fulfill domestic needs, and the skill was passed from mother to daughter and was little affected by fashion (Crowfoot et al. 2006: 72–5). In the 17th century, Sámis bought woolen mittens from peasants and merchants to be worn inside fur mittens (Itkonen 1944: 12–3, 43; 1948a: 358). It is thus no surprise that there was a fragment of a mitten made by the naalebinding method in a Mukkala grave.

Knitting is a fairly new innovation, which spread in the 15th and 16th centuries throughout Europe (Hoffman 1967: 425–8). One of the earliest examples of knitting in Northern Europe is a mitten fragment found in Jöuga, Estonia, and it is dated to the end of the 13th or the beginning of the 14th century (Peets 1987: 108). However, one would not expect to find socks in a 17th-century context like Mukkala, because the Sámis have had a strong tradition of using hay in their fur shoes. There was plenty of suitable hay to be gathered and prepared by Sámi women and, at least in the 19th century, it was available by trade, too (Itkonen 1944: 52, 88, 124; 1948a: 372–6). In general, Sámi people replaced shoe hay with woolen socks only at the end of the 19th century (Itkonen 1948a: 357). Socks were neither mentioned as a merchandise or as a good to pay taxes with; this indicates that they would have been made for domestic use only. For the Sompio Sámis the most obvious place to obtain socks was around Lake Kemijärvi. As the annual migration of the Sompio Sámis included fishing in Lake Kemijärvi they were regularly in contact with the Finnish peasants who had begun to populate the area in the beginning of the 17th century (Itkonen 1948a: 112–3).

Was it only socks that moved from Lake Kemijärvi to Sompio? Shoe hay was a free and practical solution for insulating feet against both cold and heat. Woolen socks were no better than hay and it was hardly a question of fashion either (see also Manker 1961: 189). Most probably, some Finnish peasant daughters were married to Sompio Sámi men and the women with their knitting skills —combined perhaps with their ignorance as to how to use shoe hay — caused a considerably early replacement of hay with socks in the Sámi community. Also, the Sompio women of Finnish origin may have been responsible for the possible mitten made by naalebinding; moreover, the weaving tablets found in Juikenttä were perhaps left behind by them, too. It is probable that Sámi men were required to have some knowledge of Christianity before they could be married to Finnish peasant daughters, and this superficial knowledge of Christianity is reflected in some of the grave goods in Mukkala.

Conclusions

The finds of the Mukkala burial ground represent a Forest Sámi culture that later became extinct. The burial customs and grave goods reflect the many temporal layers of a mid-17th-century Sámi culture. Due to the remote living area, the Sompio Sámi population had preserved some of the pre-Christian burial customs, like the wrapping of the deceased in skin or fur. These burial customs, however, do not belong exclusively to the Sámi tradition, as they were known at large by hunting populations in northern Eurasia.

Remoteness, however, did not prevent the Sompio Sámi from contacting neighboring peoples and from obtaining goods from them. Yarns, fabrics, and accessories were acquired by trade and, as such, these represented a foreign material impact on the clothing. However, choosing types and colors of the fabrics, sewing them into a desired pattern and connecting accessories to them were the cornerstones in creating the Sámi tradition. Ribbons may have been the only textile manufactured from yarns to a ready-made product by the Sompio Sámi and even here the possibility of exchange with other Sámi peoples cannot be excluded. As ribbon making did not necessarily require any equipment, it is no wonder it began to flourish among the Sámi at an early stage.

Knitted socks and possibly the accessories made by naalebinding were not obtained via trade. They refer, rather, to a personal connection to the manufacturer. In the Sompio Lapp Village, socks seem to have replaced shoe hay, a traditional method of insolation, at an exceptionally early stage. This may indicate intermarriages between

Sompio Sámi men and the daughters of the Finnish peasants living near Lake Kemijärvi. In support of this hypothesis, intermarriages in Kemijärvi parish are mentioned in the earliest surviving records at the very beginning of the 18th century (Rytkönen 1990: 88).

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Endnote

1) The connection between these two neighboring Sámi populations, the Forest Sámi and the Skolt Sámi, should be studied in more detail in the future. They shared similarities not only in their material culture but also in their livelihood, as they both lived mainly on hunting and fishing and put relatively little weight on reindeer herding (Kortesalmi 2007: 280, 283). As potential evidence for contacts between the two populations, reindeers were documented to roam naturally between these two areas, which also obliged the Savukoski-Sompio herders to follow their animals into the Skolt area (Kortesalmi 2007: 286–7).

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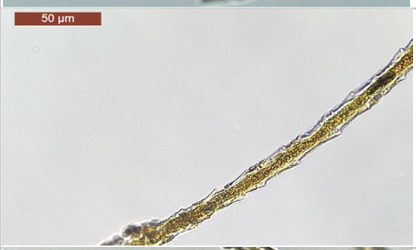
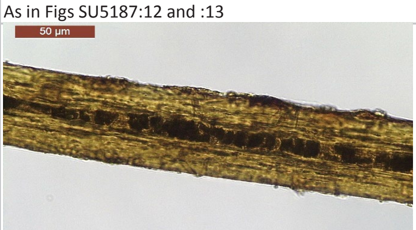
Appendix

	catalogue number (SU)	grave	function	identification	diagnostic fibre properties
	5187:4	I	fur-shoes	*Alces alces,* hair from feet or head	The guard hairs are 1,5-2 cm long and 60-130 µm in diameter. The medulla is filled lattice type with round or polygon shaped cells. The cuticular scales are mosaic-like. Notably, the hairs have a clear cortex and a straight root section. The hairs have the best match with reference samples collected from elk's feet and head.
	5187:4a	I	fur-shoes	*Alces alces,* hair from feet or head	See above
As in Figs SU5187:4 and :4a	5187:4b	I	fur-shoes	*Alces alces,* hair from feet or head	See above
	5187:5	I	unknown	Cervidae	The guard hairs are about 2 cm long and 200-240 µm in diameter. The medulla is filled lattice type with round or polygon shaped cells. The cuticular scales are mosaic-like.
	5187:12	III	fur-pouch?	Mustelidae/Vulpes	The hairs are 2-4 mm long. The guard hairs are about 25 µm (proximal part) and fine hairs 10-15 µm in diameter. Most of the hairs are fine hairs. Their medulla is cloisonné /amorphous and the medullary index is 0,7. The cuticular scales are in the proximal part petal-like with prominent scale margins.
	5187:13	III	fur-pouch	Vulpes / Mustelidae	See above
As in Figs SU5187:12 and :13	5187:14	III	fur pouch?	Vulpes / Mustelidae	See above
	5187:14	III	wrapping?	*Ursus arctos*	The guard hairs are 3,5-7 cm long and the shaft is 70-90 µm in diameter. The cross-section is round. The medulla is narrow and unicellular with gaps. The cuticular scales cannot be observed.
As in Fig SU5187:14	5187:15	III	wrapping?	*Ursus arctos*	See above

	5187: 41/42	V	skin item	indet.	
As in Fig SU5187:5	5187: 50	V	wrapping	Cervidae	As in SU5187:5. The diameter of the guard hair is 150 µm.
	5187:51	VIII	loose hair	Cervidae / *Alces alces*	As in SU5187:5. The diameter of the guard hair is 300-330 µm. On the base of the width of the hair it is tentatively identified as elk.
As in Fig SU5187:51	5187:53	VIII	loose hair, presumably from wrapping	Cervidae	As in SU5187:5. The diameter of the guard hair is 110-260 µm.
	5187: 55	VIII	wrapping	Cervidae	As in SU5187:5. The diameter of the guard hair is max 240 µm. The sample contains several wine-glass shaped root sections.