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Kirkinen, Tuija

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Microscopic fibres in soils – The accumulation of textile fibres and animal hairs at the 6th–11th-century CE Kvarnbo Hall settlement site on the Åland Islands, Finland

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ABSTRACT

Microscopic animal and plant fibres detected in archaeological contexts are a valuable source of information regarding textile production, use-histories of artefacts and in studying mortuary practices. At the same time, recent research on microplastic pollution has revealed the ability of fibres to move even long distances and accumulate in various terrestrial and aquatic contexts. In this paper we discuss the accumulation of 100–1000-μm-long animal hairs, bird feather barbules and textile fibres at Kvarnbo Hall, a Nordic Late Iron Age high-status settlement site in the Åland Archipelago, Finland. The hairs and barbules detected in soil samples reveal important information on the use of furs and downy feathers at the site. However, our study reveals that the microparticles sampled in the 6th–11th-century contexts represent not only the prehistoric phase of the site but can also be ascribed to the later land-use history of the area. We also speculate that long-distance air-borne particles might be one possible contamination source of fibres.

1. Introduction

In archaeology, the knowledge of garments and household textiles is built on the cloth-type remains (Harris, 2008) detected especially in graves but also in bogs, glaciers, salt mines, and underwater sites (e.g. Lukešová et al., 2017; Mannering et al., 2010; Rammo, 2015; Vedeler and Bender Jørgensen, 2013). The challenge in research is that textiles, skin and fur are organic soft tissues, which preserve only in contexts where the microbial activity is low. These requirements are met in dry, frozen, anaerobic, and salty environments as well as in the proximity to alloys extracted from metal items (e.g. Janaway, 2002; Rast-Eicher, 2016, 15–31).

The evidence of textiles and fur can also be reached through minuscule fibres detected on the surfaces of artefacts (Hardy et al., 2013; Robertson et al., 2009), in dental calculus (Gismondi et al., 2018; Juhola et al., 2019), soil samples (Ahola et al., 2018; Kirkinen et al., 2020a; Mannermaa and Kirkinen, 2020) and in pollen samples collected from the sediments of archaeological sites (Bar-Yosef et al., 2011; Chkhatarashvili et al., 2020; Kvavadze and Gagoshidze, 2008; Song et al., 2017). By microscopic fibres we refer to 100–1000-μm-long animal hairs, feathers and plant fibres, designated in the research literature as microparticles (Henry, 2020, 2), microfossils, microresidues or, in sediment samples, as non-pollen palynomorphs (NPP, Shumilovskikh and van Geel, 2020, 68).

In this study, we analysed soil samples for fibres at the 6th–11th-century CE Kvarnbo Hall settlement site on the Åland Islands, Finland. At the site of Kvarnbo Hall, traces of dwelling houses and a large long-house, as well as the find material diagnostic of a Late Iron Age upper societal strata (Ilves, 2015a, 2018; Ilves and Darmark, 2020) strongly indicates an elite settlement site. In high-status communities, the wealth was invested not only in precious metals and other materials such as glass, but also invested in prestige artefacts that are archaeologically difficult to detect. Among these are furs and luxurious textiles such as silk, valuable textile colourants, and down-stuffed pillows and quilts (see Rast-Eicher, 2016: 291).

Therefore, the examination of fibres at Kvarnbo Hall aimed to find

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evidence of the variety of textiles and furs worn and fabricated at the site and thus widen our understanding of the material culture of an elite site. As the microscopic findings can be air-borne, transported by water or eddied in soils, possible sources of contamination are an essential issue in evaluating the results. Equally, we identified textile fibres, which turned out to mostly represent the later land-use history of the site, as well as air-borne particles and contamination during the research process.

2. The Kvarnbo Hall settlement site

Situated on the main island of Åland, in the parish of Saltvik, the site of Kvarnbo Hall was identified in 2012 through an infrared aerial photograph from the 1970s that displayed a number of anomalies, including a 45 m-long and 15 m-wide impression of a longhouse structure. Figs. 1 and 2. Following the identification of the site, Kvarnbo Hall was approached using a number of investigative techniques ranging from metal-detecting and ground-penetrating geophysical surveys to both test- and large-scale excavations (Ilves, 2015b, 2017).

The topsoil removal of the central area with the longhouse feature as indicated on the infrared aerial photo covered 1065 m^2, within which a total of 288 features were discovered and investigated. The majority of these can be interpreted as postholes, but a few hearths/ovens were found, as well as a few patches of cultural layer (Ilves and Darmark, 2020, Fig. 7.6). There are, however, a few carefully stone-lined postholes that are surprisingly robust – indicating the relatively good preservation of these features, reaching depths of over 45 cm.

Strategically situated on the North-South passage through the Åland archipelago in the Late Iron Age, the Kvarnbo Hall settlement site has been understood as an autonomous hall farm with involvement in trade as a background for its social position (Herschend, 2022, 232–234). The outstanding artefacts found in the topsoil, including personal ornaments of silver and bronze, but also exotic and exquisite belt mounts, glass sherds from different drinking vessels as well as objects pointing towards trade, such as fragments of Arabic silver coins and a weight, testify to the importance of the site throughout the Late Iron Age.

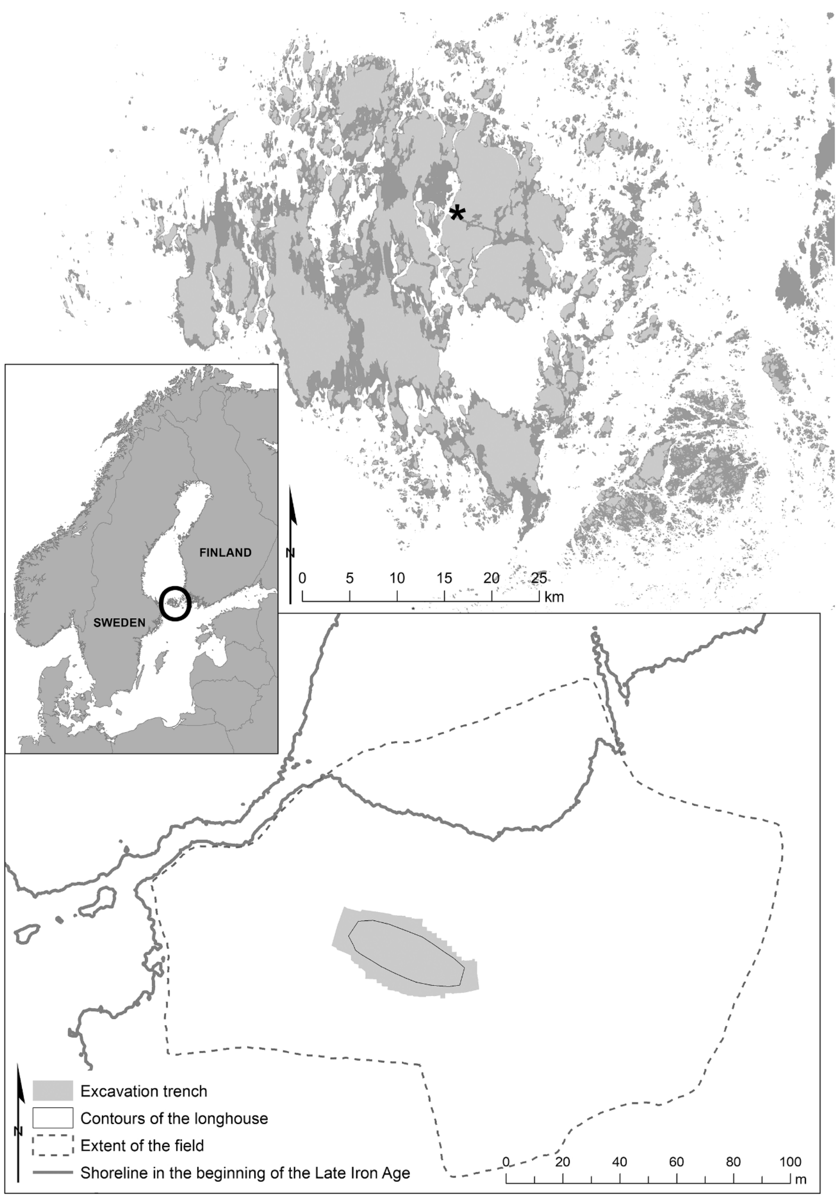

Fig. 1. Location of Kvarnbo Hall settlement site in Åland Archipelago. Drawing: K. Ilves.

Fig. 2. A drone overview of Kvarnbo Hall from NE in 2016. Photo: D. Löwenborg.

3. Material and methods

3.1. Sample collection and preparation

During the large-scale archaeological research excavations in 2016, a substantial number of archaeological features were uncovered and investigated. Although only few prehistoric house structures were identified with certainty, the number and density of postholes indicate many and partially overlapping structures. All archaeological features recovered on an in situ feature level were investigated by hand. The features were first cut lengthwise whereby the cultural sediment was dug out contextually. Thereafter, a profile ditch was excavated in order to clarify the form and the dimensions of the feature. After the section documentation, all feature sections were sampled for soil analyses by extracting about three tablespoons of sediment from the bottom half of the feature. The samples were stored in plastic zip bags.

Of the total of 288 soil samples, 21 samples were chosen for fibre particle research. The selected samples covered contexts, which were considered to be Late Iron Age and undisturbed. As an exception, one sample (A192) was selected from a feature of modern character. The samples were connected to features related to three identified house structures predating the longhouse at the site as well as to features without clear spatial relation to identified constructions at the site (Fig. 3). Of the selected contexts, nine have been 14C dated with 15 samples of short-lived material, such as nutshells and cereal.

For the microparticle analysis, a subsample of 50–100 g was separated and floated in 1 dl of distilled water. The extracted material was stored in 15 ml centrifuge tubes. Most of the tubes were centrifuged for 7 min in 2500 rpm by TD4A-WS desk centrifuge. The samples were prepared for transmitted light microscope examination by pipetting the material on microscope slides and by covering them with coverslips. The samples were sealed between the glass-slides and coverslips with

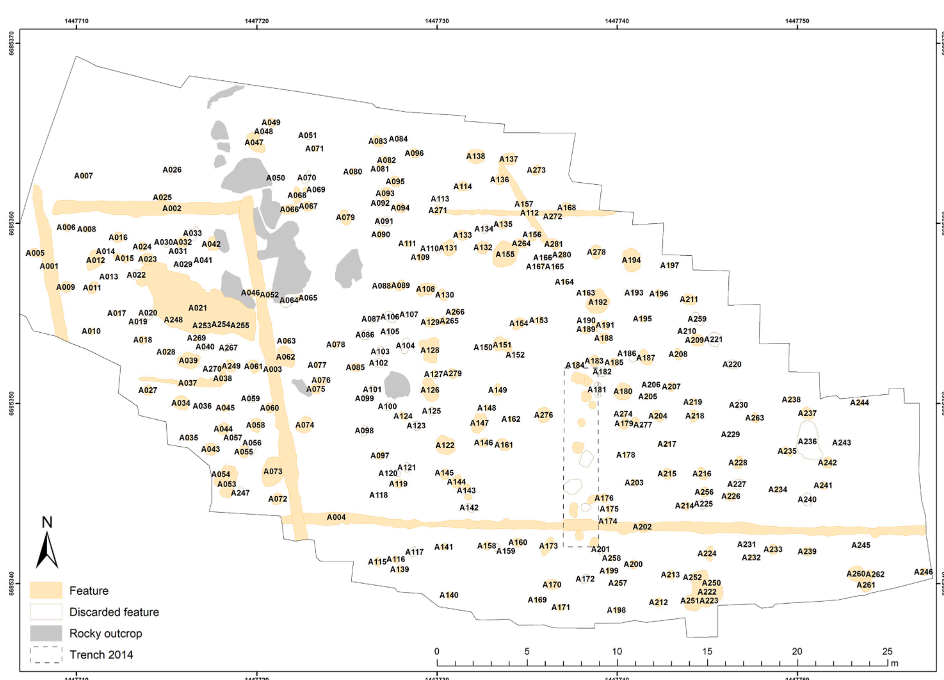

Fig. 3. The Kvarnbo Hall excavation area with features, which all were sampled for soil analysis. Drawing: K. Ilves.

transparent nail polish. The material was studied with visible and polarised light microscopy, using a Leica DM 2000 LED microscope and Amscope 40X-1600X Advanced Professional Biological Research Kohler Compound Microscope with 100x–400x magnification. The material was documented with Leica ICC50 W and 10MP USB3.0 cameras and measured with LAS V4.13.0 and LAS Core software.

The contamination of samples during the research was minimised by cleaning the surfaces of the research room before each sample and by collecting control samples by a 10-cm-wide water bowl trap the content of which was examined once a week. Controls were collected also from the wiping materials. The time that the samples were uncovered was as short as possible, only 2–5 min. However, in the present context it is important to emphasise that the sample bags were after the collection in the field stored for some months at a room temperature with an open bag mouth to allow the samples to dry out in order to avoid molding. Furthermore, the used storage facility was exposed to possible contaminants.

A selection of seven slides were re-examined in Aalto University Nanomicroscopy centre focusing on plant fibres. Before examination each glass-slide was wiped with distilled water to exclude all external contaminations. The samples were studied with a Leica 2500 transmitted light microscope, imaged with Leica MC190HD camera and measured with LAS V4.13.0 software.

3.2. Identification of fibres and hairs

For the morphological identification of mammalian hairs, the keys on Rast-Eicher (2016), Teerink (2003), and Tóth (2017) were applied. The fibres were also compared with a reference collection of Fennoscandian species. Feathers were identified by their morphology after Dove and Koch (2011). The terminology followed mainly Tóth (2017) and Dove and Koch (2011).

Textile fibre identification was done by observing the fibre diameters and morphological features, which had overlappings with both cotton and undegummed silk. In the literature, reported diameters of cotton vary from 11 to 18 µm (Letellier-Willemin, 2006, 24) to 18–25 µm (Dochia et al., 2012, 13) and 15–30 µm (Rast-Eicher 2016, 75). In degummed silk, the reported diameters of filaments have been 10–12 µm, but double in undegummed silk (Rast-Eicher, 2016, 283, 284). Wild silk varies a lot according to the fibre shape and diameter by species (Malay et al., 2016). In addition, the visual appearance of cotton fibres can be reminiscent of undegummed silk (Rast-Eicher, 2016, 55, 59), or even of flax with narrow lumen and cross markings (Letellier-Willemin, 2006, 3124; Suomela et al., 2020). In heritage cotton fibres, the thickenings at the edges of the fibres are often more visible, which makes it difficult to distinguish from undegummed silk.

4. Results

4.1. Wild animal hairs and feathers

We identified 16 mammalian hairs, the length of which was 0.4–20 mm. Hairs were detected in postholes and especially from the furnace A032 (four hairs) and the hearth A054 (four hairs) structures. The identified wild mammalian specimens were lynx (*Lynx lynx*) and Mustelidae, discovered in the postholes A006 and A016. In addition, two possible hare (Lagomorpha) underhairs were recovered in the furnace structure A032. The underhairs from postholes A252 and A281 reveal similarities with Mustelidae, small rodents or insectivora. Eight hairs remained unidentified. See Fig. 4 and Supplementary material 1.

We also identified 20 bird-feather fragments, which originated mostly from the plumulaceous (downy) parts of the feathers. The length of the barbules was 0.2–1.1 mm, and the two barbs were 2.2 and 7.6 mm in length. Five barbules were identified as originating from waterfowl (Anseriformes), whereas the others shared no diagnostic features. Feather fragments were detected from postholes and furnace structures. Three fragments were identified in sample A192 too, which has been interpreted as a more modern structure.

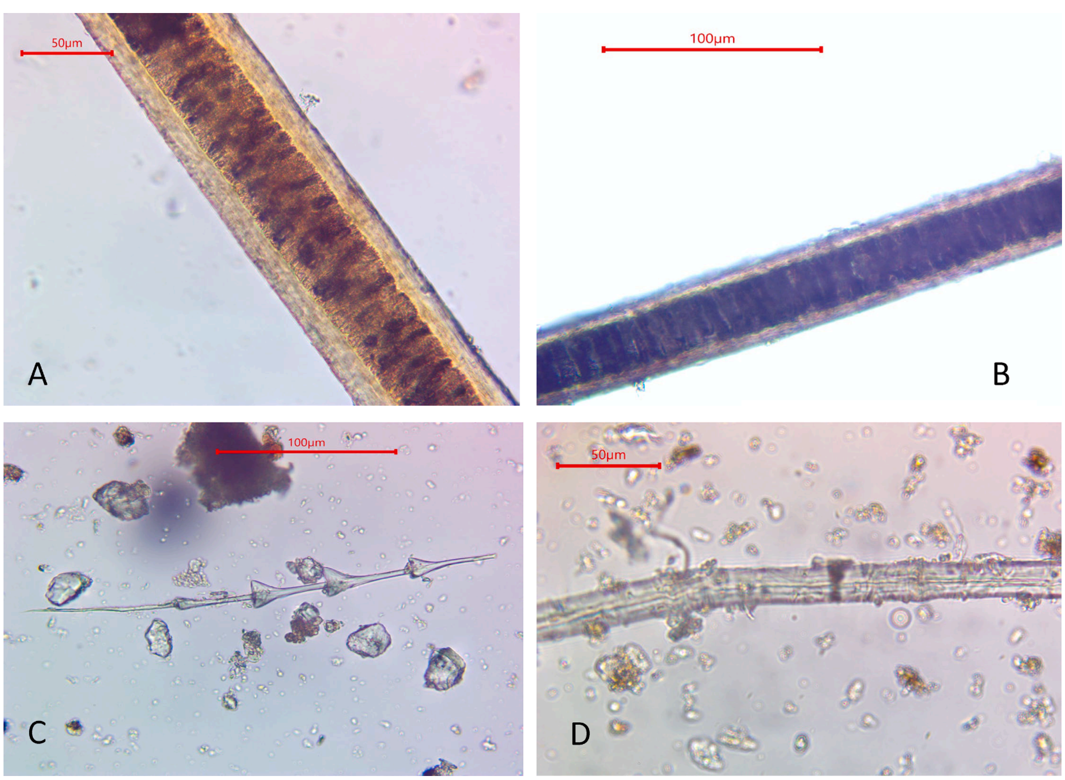

Fig. 4. Animal hairs and bird barbules recovered from Kvarnbo Hall settlement site. A) *Lynx lynx* (sample A006); B) Mustelidae (A016); C) Anseriformes (A032); D) bast fibre (A211). Photos: T. Kirkinen.

4.2. Textile fibres

Two of the hairs originated from sheep and based on the visually blue colour of the fibre at least one of these is from the remains of wool textile. Additionally, altogether 61 fibres that were designated as textile fibres were found (see Supplementary material 2). These were all very small, only 0.2–1.6 mm long, and their diameters varied from 8 to 29 µm. Textile fibres were identified by their longitudinal characteristics and diameter (Kozłowski, 2012 [ed.]; Rast-Eicher, 2016; Smole et al., 2013). Due to this unilateral observation and the uncertainty it caused, some of the found fibres remained unidentified. The fibres shared features of cotton and silk, for example, many fibres had cotton-like convolutes, or irregularities typical of wild silk. Some had cross-marks typical of plant fibres, while most had a longitudinal line that could indicate lumen that is a plant fibre feature, or which appears in undegummed silk, too (See Figs. 5 and 6). Hence the fibres were single and microscopic; it was not possible to prepare cross-cuttings to observe their cross-sectional features that would have ensured identification. Silk has, depending on the species, a triangular cross-section, whereas cotton has long and flat lumen and its fibre shape resembles a bean or the letter C (Rast-Eicher, 2016; Smole et al., 2013). Thus, we refer to the detected fibres as cotton-silk lookalike fibres, since the identification remains unclear. Fibres cannot be identified reliably when the observation is based on only a single fibre of a limited length. See Fig. 6.

Additionally, one 1.6-mm-long uncoloured bast fibre was detected in posthole A211. One potentially synthetic fibre based on longitudinal characteristics and diameter was found in furnace A032. The same feature also included an exceptionally thin – less than 10 µm – fibres or possible roots. No further identifications were possible.

5. Discussion

5.1. Animal hairs and feathers

At Kvarnbo Hall, a mustelid, lynx, sheep and possible hare hairs were recovered. Especially lynx hair is of importance, as it has been archaeologically identified in mainland Finland only twice. First, in the Luistari cemetery in south-western Finland, a wide bronze-plated knife sheath (KM 18000:1703) of the 11th century CE was lined inside with a lynx skin (Kirkinen et al., 2020b). Second, the felids' hairs in a small child's Grave 139 in Luistari might have originated from a lynx skin (Kirkinen 2015). In addition, burnt lynx third phalanges found in Kalanti Kalmumäki cremation burial might indicate the cremating of a lynx skin together with the deceased (Lahtiperä, 1975). However, in Sweden lynx third phalanxes have been found especially in 4th–10th-century female burials, indicating the placing of lynx skins in graves (Zachrisson and Krzewińska, 2019). As Torun Zachrisson and Maja Krzewińska (2019) have concluded, lynx skins were valuable items, which were traded for a good price.

Mustelids hair originates either from a stoat (*Mustela erminea*), least weasel (*Mustela nivalis*), pine marten (*Martes martes*) or European mink (*Mustela lutreola*) skin. In mainland Finland, Mustelid hairs and pieces of fur have been identified e.g. in the Late Iron Age cemeteries in Luistari and in Kekomäki in Kaukola (Karelian Isthmus, current Russia). Mustelid skins could have been used for collars, linings, small pouches and for decorations, and they were traded in the Viking world as far as the Asian markets.

The species composition – sheep, mustelids and lynx differs from the osteological assemblage in Kvarnbo Hall, analysed by Ylva Bäckström (2017), according to whom most of the bones originated from sheep/goat, cattle and seal. No mustelids nor lynx was recovered in the osteological find material, the only fur animal bones were those of two red fox (*Vulpes vulpes*) bones out of the analysed 4234 bones recovered at the

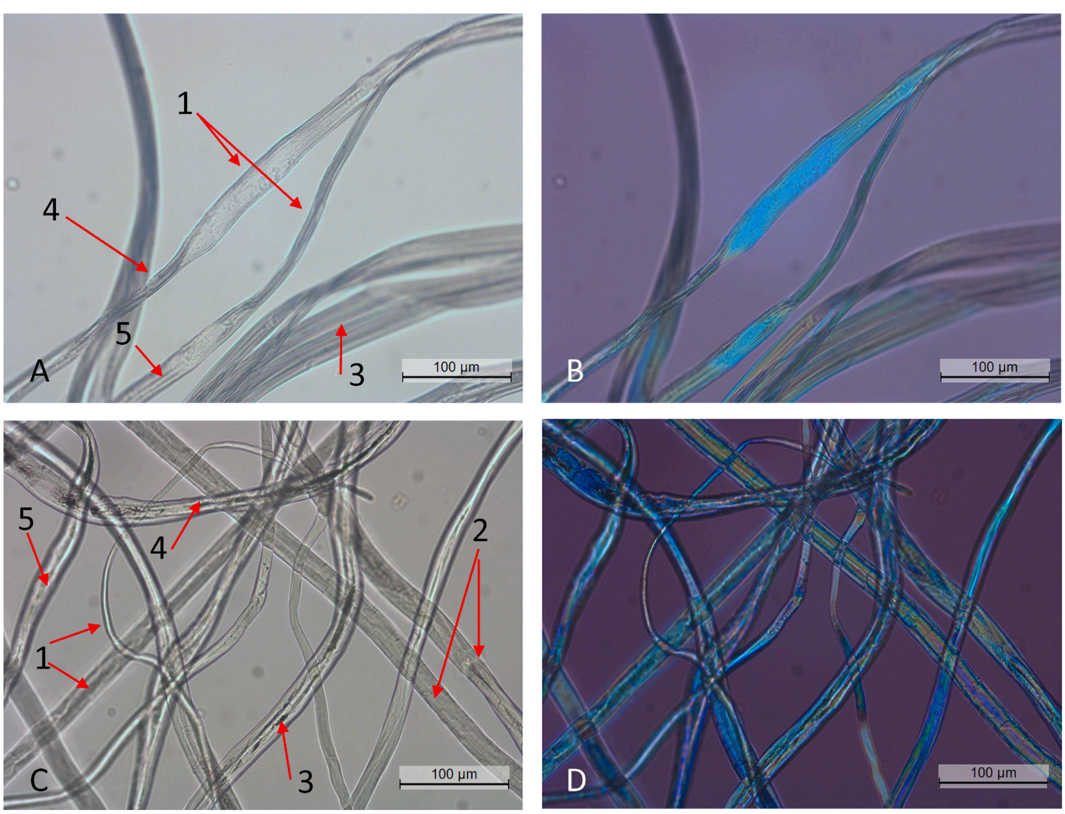

Fig. 5. Wild silk, A) unpolarized and B) polarized microscope images; cotton (unprocessed seed fibres of *Gossypium arboretum*) C) unpolarized and D) polarized microscope images with variance in 1) diametres, 2) cross-marks, 3) longitudinal lines, 4) convolutes, and 5) undegummed-like features. Photos: K. Wright.

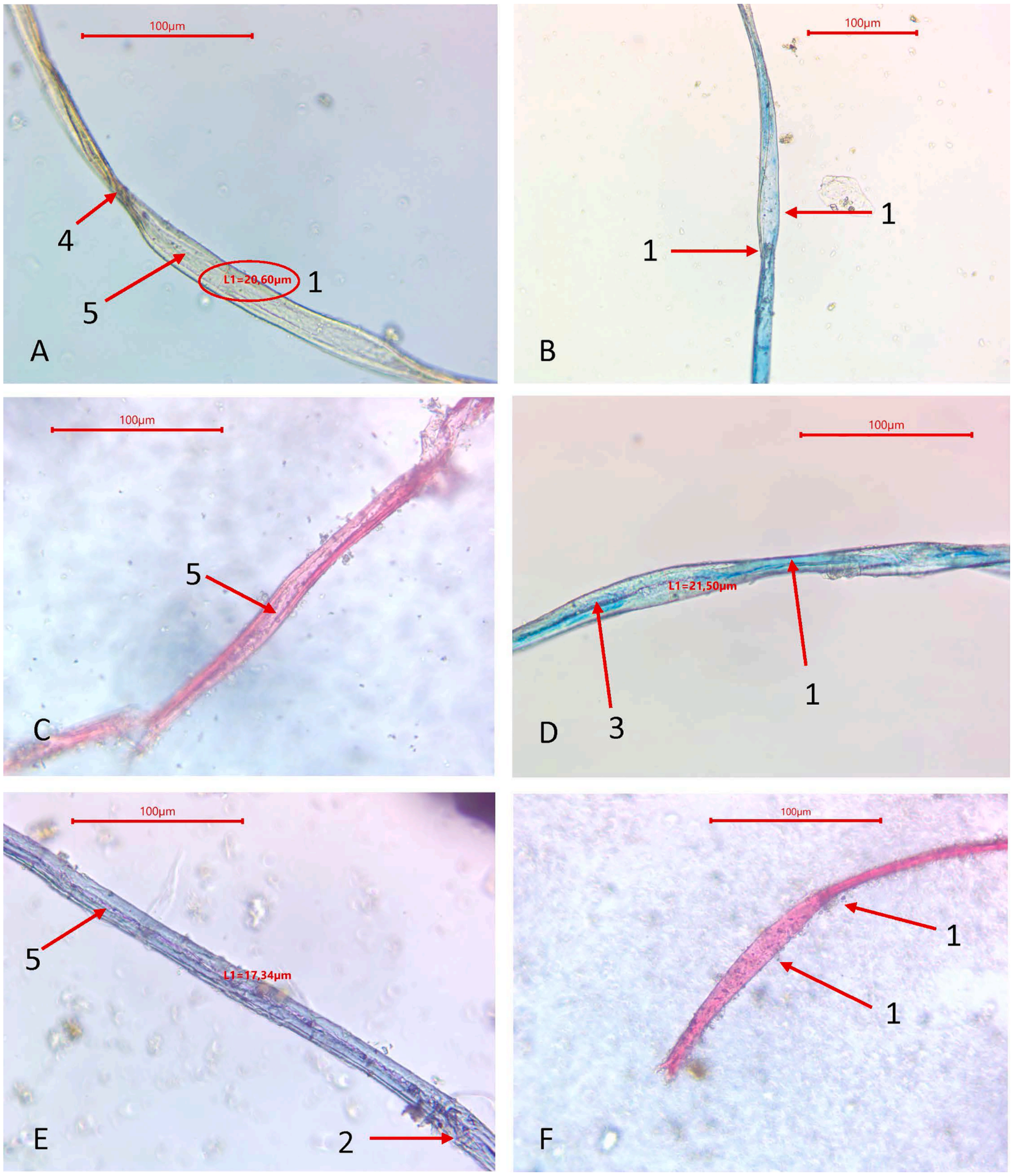

Fig. 6. A selection of textile fibres recovered from Kvarnbo Hall settlement site. A) A054 K29; B) A054 K21; C) A016 K2; D) A054 K9; E) A192 K5; F) A032 K41; G) A032 K53; H) A032 K48; I) A032 K45; J) A032 K42; K) A032 K50; L) A211 K4 with variance in 1) diametres, 2) cross-marks, 3) longitudinal lines, 4) convolutes, and 5) undegummed-like features. Photos: T. Kirkinen and K. Wright.

site. Three bones were identified as mountain hare (*Lepus timidus*) bones, and Lagomorpha was possibly identified also in the hair material. The lack of seal and cattle hairs might indicate that the hides were prepared outside the most intense settlement area, which is just logical.

Besides hairs, also 20 bird feather fragments were detected from the soil samples. Downy feathers have been recovered in research in Finland (Kirkinen et al., 2020a), Norway (Dove and Wickler, 2016), and Sweden (Berglund and Rosvold, 2021), interpreted as remains of downy-filled pillows and blankets. Therefore, it can be hypothesised that the feathers at Kvarnbo Hall were remains of pillows or blankets, or they might be household refuse or waste connected to bird carcass preparation. Kristiina Mannermaa (2018) has studied the bird bones recovered at Kvarnbo Hall and identified, among others, common eider (*Someteria mollissima*), great cormorant (*Phalacrocorax carbo*), and great crested grebe (*Podiceps cristatus*). These results are in balance with the barbules identified as waterfowl.

When evaluating the results it is important to remember that the fibre finds emanate from undisturbed, in situ feature bottoms, from postholes as well as furnace and hearth structures that are located in the natural soil layer. The cultural layers of the site have been almost completely destroyed by modern cultivation. However, there were some remains still existing and we analysed one sample A222 of the cultural layer, but we recovered no fibres nor hairs.

5.2. *Textile fibres*

5.2.1. *Identification and dating*

We detected a great number of cotton-silk lookalike fibres, several unclassified fibres but only one with the possible appearance of a synthetic fibre. Studying only individual fibres creates additional challenges in an already demanding fibre identification. The dating of these fibres would have required a much larger sample size than just a

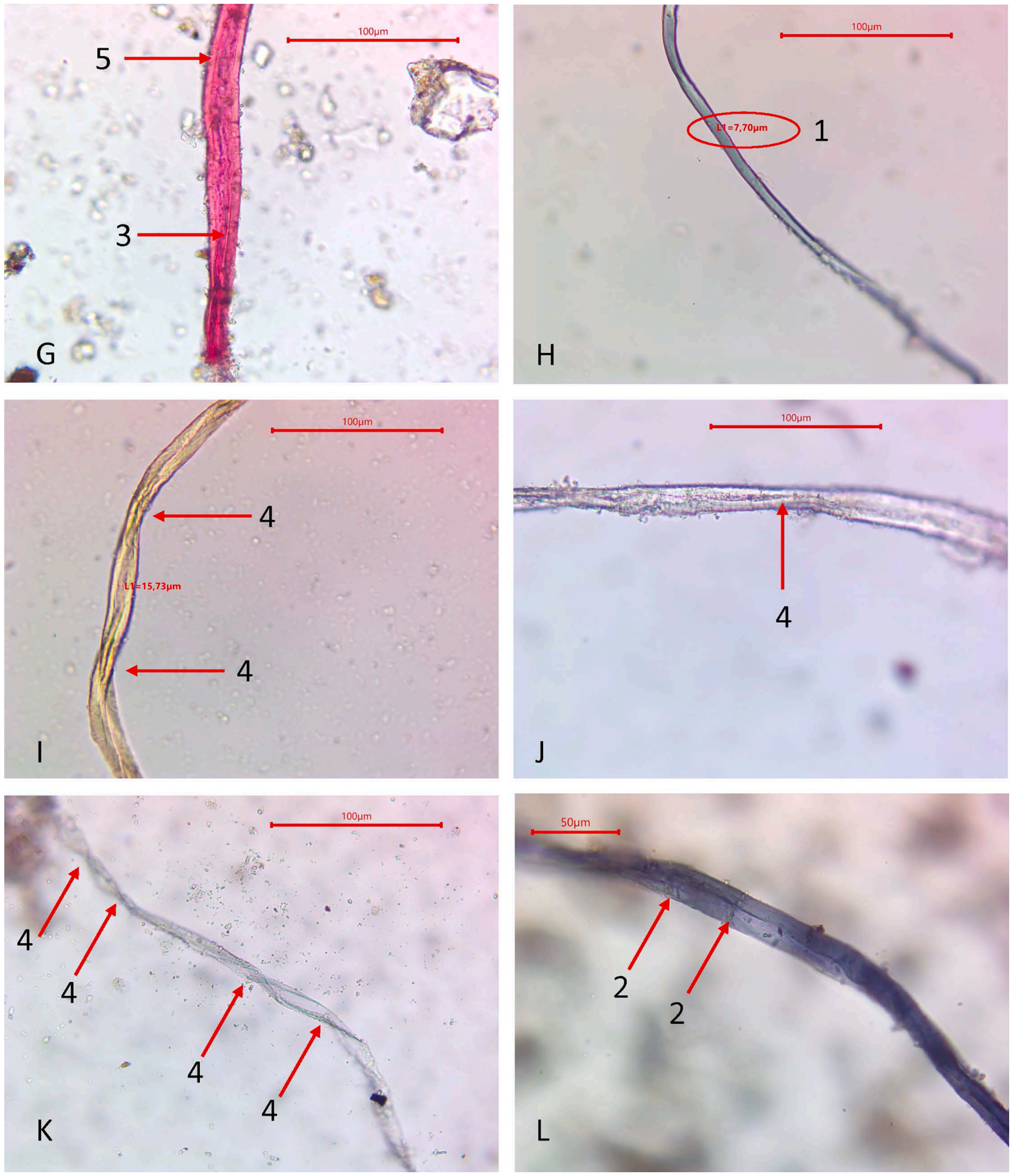

Fig. 6. (*continued*).

microscopic fibre. Of course, not all methods of analysis were feasible in the identification process due to limitations of equipment. By using special FTIR methods (e.g. ATR-FTIR, mATR-FTIR, r-FTIR) it might have been possible to measure chemical compositions in individual fibres at least to determine the fibre type (Garside and Wyeth, 2003; Peets et al., 2019). Respectively, Raman spectroscopy would have been a possibility (Bordes et al. 2017; Edwards et al. 1997), since like FTIR, it can distinguish between protein and cellulose materials by their spectral fingerprints and can be used for individual fibres. However, in the case of the Kvarnbo Hall samples, spotting the sparse and very small fibres on glass slides was considered very challenging for Raman and micro-Raman instruments. These methods work with specimens that contain yarns or textile pieces (see Vandenabeele et al., 2005), or the samples would require much more fibres that were present in the Kvarnbo Hall samples. Degradation of fibre material due to ageing can create challenges for fibre identification (Fanti et al. 2013), and thus measuring modern reference fibres should naturally precede the measurements of the archaeological fibres in all methods.

Using confocal microscopy in observing cross-sectional view from the same sample on the glass slide would be possible (Corte Tedesco and Anthony Browne, 2021; Kirkbride and Tridico, 2009). Especially in distinguishing between silk and cotton this quality would have eased the definition. Although, a cross-sectional view of a single fibre should not be used as an identification parameter due to natural variation (Lukesova and Holst, 2021; Suomela et al., 2020). Even grounding identification on the fibre diameter is inaccurate with natural fibres due to variation even within the same fibre source.

Speculation could be based on the condition of the fibres. In unfavourable conditions, such as humidity, temperature or acidity, microbial activity is quickly and clearly visible on fibres (Garside 2022, 342). These can be seen for example as eroded holes, mould spores or inessential constituents on the surface of the fibre. Also dyed colours usually get dull in soil conditions. Then again, in favourable conditions, due to frost, salt, bog or such, textiles can survive almost intact for millennia. Most of the cotton-silk lookalike fibres were in perfect condition without any traces of microbial activity or the dulling of colour. Because only little organic material such as wood has survived in the soil conditions at the Kvarnbo Hall site, it could be speculated that these fibre finds are from more recent sources.

5.2.2. Possible origins and accumulation

One possible explanation for the Kvarnbo Hall's fibres is the accumulation of fibre in soils due to modern human activity. The presence of fibres could originate from the textile waste used commonly as toilet paper, as even precious textiles such as silk have been found from latrine depositions (Grömer, 2017, 91; Rammo, 2015, 109–110). According to Henry Nygård (2004, 108–109, 146–156), excreta was even exported from the cities to the farms for fertilising the fields during the 19th and early 20th centuries to fill the gap of suitable manuring substance. It is reasonable to assume that the farms recycled their own waste in the same way. The distance between the mediaeval Saltvik Church and the excavation area is only about 75–125 m, so in theory it cannot be excluded that the recycling at the church might also have been the source of silk or cotton fibres.

Another explanation for the fibres is airborne fibrous particles, the microplastic fibres of which have been widely documented (Dris et al., 2016, 2017; Trainic et al., 2020; Wright et al., 2020). Although plastic and synthetic microfibers have been discussed due to their ecological impacts, it is the natural fibres (mostly cotton) that form the majority of airborne fibrous populations and can be detected even in remote areas (Athey and Erdle, 2021; Dris et al., 2016, 2017; Stanton et al., 2019).

In both cases, the moving of microparticles from soil surface or plough layer to mineral soils is possible and documented for example in phytoliths (Fishkis et al., 2009), charred microparticles (Asscher and Boaretto, 2019), and parasites (Camacho et al., 2020). One of the most elemental factors in microparticle movement is bioturbation, i.e. the disturbance of the soil or sediment by living things such as insects, bacteria, and roots (Asscher and Boaretto, 2019). In this process, the grain size of the soil is an elemental factor, namely the coarser the soil, the bigger or more probable the movement (Cabanes, 2020, 257).

Afterall, we cannot exclude contamination during the field work and in the lab. For example, some fibres might originate from the clothing of excavation staff, and fibres might have accumulated during the processing of samples. On the basis of our experience, single modern fibres have been found in analysing, for example, Mesolithic soil samples; but their number has been really low, 1–5 fibres per site. Their origin might have been, however, that of airborne microfibres.

There are numerous moments of possible contamination on the path of a sample from the moment of excavation to being sampled between slides for microscopy observation. Contamination fibres can originate from the clothes or tools of the excavator, or from the lab personnel, or be air-borne at the site before the soil sample was stored in a plastic bag. It can be from the time the plastic bags were open for drying, or from the clothes or be air-borne when the researcher has prepared the samples.

Although the accumulation of textile fibres might originate from different sources and time periods, it cannot be excluded that part of the fibres originate from the Late Iron Age. At Kvarnbo Hall, the neutral and slightly alkaline soils (pH 7.07–7.44) have the potential for preserving cellulose-based fibres such as cotton (Janaway, 2002, 382; Rowe, 2010, 45). Little is known of the household textile of that period, because no textile material has been found in the few studied Late Iron Age settlement sites in Finland. The preservation of organic material is seldom good, such as in Tursiannotko settlement, which unfortunately had no fibre remains (Lesell et al., 2017). Household textiles might have consisted of wool and plant fibre textiles and furs, and less commonly of silk. Usually the textile finds of that period are from inhumation burials, where these materials have survived only in direct contact to bronze jewellery (Lehtosalo-Hilander 1984). Same materials are found from Swedish settlement sites too, like Birka (Geijer 1938).

Taking into consideration the dating of the Kvarnbo Hall site, both cotton and silk fibres are theoretically possible findings, even from the Late Iron Age, since these fibre materials existed in Europe at that time. Concrete evidence of long-distance transport include the rich amounts of silver dirhams of Near Eastern origin (Talvio, 2002) and silk fabric finds of Viking Age Finland and Scandinavia (Vedeler, 2013, 2014). In Finland, there are a few Iron Age silk finds, all connected to rich burials (Tomanterä, 2006, 45; Lehtosalo-Hilander, 1982a, 171, 1982b). In Late Antiquity and Medieval textiles, *Bombyx mori* silks were mostly used as reeled, unspun and degummed, while spun silk can indicate a Mediterranean origin; undegummed silk can, on the other hand, refer to a Central Asian origin (Rast-Eicher, 2016, 277–279, 285).

In the Old World, two cultivated cotton species were available in prehistoric times, *Gossypium arboreum* and *G. herbaceum*, with some wild species as well *(*Rast-Eicher, 2016, 73*)*. It is theoretically possible that cotton arrived in Scandinavia as a Roman import during the Late Iron Age, but the evidence is lacking (Lukešová et al., 2017). From Western Europe, all of the few Iron Age cotton finds are connected to the time of the Roman Empire and its trade network (Wild and Wild, 2014). In the 10th century, cotton was cultivated in Palestine and Syria; it is even known that cotton was used in different textile types, which could also include silk threads (Shamir, 2019). During the Crusades, increasing imports of cotton made their way from the Levant to Europe where, already in the 1200s, a guild of cotton beaters existed to control the work (Rast-Eicher, 2016, 74). In certain textile types, cotton was used as weft with linen warp (Cardon, 1995; Mazzaoui, 2008). The first confirmed cotton findings in Finland are from the 14th century, for example in a few ecclesial textiles from Turku Cathedral (Arponen, 2011; 2015; Arponen et al., 2018; Karttila, 2014).

5.3. Comments for future research

The soil samples analyzed in this paper were collected in 2016 primarily for the Munsell colour analysis. Although they were valuable research material for fibre analysis after five years of storage, some actions would have been of importance if the material would have been collected for microparticle research. The most elemental one of these would have been the collecting for reference samples outside the actual archaeological site. This would have helped to identify the "background noise", which is typical for the area. Besides reference samples, also the analyzes focusing on bioturbation of fibres would have given information of the moving of microparticles horizontally and vertically. Moreover, the use of protective cloths and the cleaning of equipment would have reduced the contamination of fibres in the field. In the future, the possibility of analysing soil samples for fibres or other air-borne particles need to be taken into account already when planning the sampling on excavations.

As the analysing of soils for fibres is a new and developing area of research, a protocol for every step from the field to the lab should be created. In this task, the instructions given e.g. in pollen and starch research (Pearsall 2016) as well as in forensic fibre research (Robertson and Roux, 2018, with references), will be of great help. Finally, it is important to be aware that minuscule remains of organic materials do preserve in soils, by giving important information of the material culture at the site.

6. Conclusions

In this paper we studied a selection of 21 soil samples microscopically from the Kvarnbo Hall settlement site situated on the Åland Islands, Finland. The aim was to analyse the animal hair and feather fragments as well as possible textile fibres preserved in archaeological contexts. As a result, we recovered a wide variety of hairs and fibres of which only a part could be connected to the Iron Age settlement phase. Especially the rich cotton record evidenced the continuous accumulation of fibres in soils, the origins of which can be hypothesised on the basis of long-distance air-borne fibres as well as on household waste used for manuring the fields. In addition, contamination possibly occurred during the research process from field to lab, which is a well-known source of air-borne fibres.

In general, in an archaeological context, there is always a risk of contamination. It has been suggested that the archaeologists should work at excavations in hygienic conditions that are akin to that of food preparation, if not that of the surgical operation (Daniel, 1974, 6; Ryder, 2000, 19). However, modern or historical contamination cannot be excluded even by following the strictest protocol during the research process, as the sources of fibres during the decades and even centuries have been many.

CRediT authorship contribution statement

Tuija Kirkinen: Conceptualization, Methodology, Validation, Investigation, Data curation, Writing – original draft, Visualization, Project administration, Funding acquisition. **Krista Wright:** Methodology, Validation, Investigation, Writing – original draft, Visualization. **Jenni Suomela:** Methodology, Validation, Investigation, Writing – original draft. **Kristin Ilves:** Conceptualization, Investigation, Resources, Writing – original draft, Visualization, Funding acquisition.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jasrep.2022.103809.

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