Finnish shipwreck textiles from the 13th–18th centuries AD

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ABSTRACT
This article discusses textile fragments that have been found in shipwrecks off the coast of Finland. The finds have been dated to the 13th–18th centuries AD. All samples were researched with visual analysis, but XRF, FTIR, SEM and HPLC was applied to part of the finds. The fragments of a woollen 2/1 twill from the Lapuri wreck were here interpreted as the remains of a red ochre treated sail cloth. The finds from the Egelskär wreck were interpreted as remains of a sheepskin. Other discussed finds are a woollen tabby weave from the Mulan wreck, fragments of a red woollen broadcloth from the Vrouw Maria, and a woollen sock and a silken rococo petticoat with woollen batting from the Sankt Michel. The aim is to shed light on textiles that form an understudied group of Finnish archaeological textile finds.

Keywords: shipwreck textiles, visual analysis, wool, mohair, camlet, sail fabric, petticoat

1. Introduction

In Finnish archaeology the shipwreck textiles have rarely been researched. This article sheds light on these rare finds: a sheepskin; two fragments of 2/1 twill; a tabby woven fragment; a petticoat; a sock, and a napped broadcloth. All the finds were studied with visual analysis and part of them with additional analyses using FTIR, SEM and XRF to gain new insights on these finds. The results will here be discussed within the textile archaeological framework to understand the finds as fragments of their own age's culture history.

The Baltic Sea as a connector of distant shores through maritime routes has been important from prehistory to the present. The archipelago offered the sailors natural harbours for resting, preparing food and waiting for better weather. The coastal waters of Finland are relatively shallow and have tens of thousands of islands, skerries and rocks. Since the shipworm *Teredo navalis* does not live in the brackish water of the Baltic Sea, the ships that are sunk deep enough to avoid winter ice formations are preserved in relatively good condition (Leino et al. 2011, 137; Steffen and Montonen 2012, 222–229). However, of the numerous shipwrecks found in Finland only a few have been excavated archaeologically and only few of the excavated wrecks have contained textile fragments, which makes their study even more precious for the field of textile archaeology.

2. Shipwrecks with textile finds

The studied archaeological textiles have been dated to the 13th–18th centuries AD. The wrecks have been named after the island nearest the site, except the Sankt Michel and the Vrouw Maria (Map 9). These wrecks were identified according to the Danish Toll Sound register, the archive sources about the salvaged goods, the measurements made at the wrecks and the type of the ships' cargos (Ahlström 1978 and 2005; Gelderblom 2003; Matikka 2012, 90–101; Alvik 2012, 108–131).

1. Vrouw Maria
2. Egelskär
3. Sankt Michel
4. Mulan
5. Lapuri

Map 9. Placenames mentioned in the article of Vajanto. Illustration: K. Vajanto.

2.1 The Lapuri wreck

The Lapuri wreck is situated in a natural harbour at the eastern corner of the Gulf of Finland in a place that has excellent connections to both east and west. It is known that the Vikings' maritime route to Constantinople followed the Gulf of Finland (Lehtosalo-Hilander 1984, 319–322). Because she is clinker built, as were the Viking ships, she was interpreted as a Viking ship in the first research (Alopeus 1985 and 1995).

The *Lapuri* wreck is 13.8 x 4.4 m in size and made of oak. The wooden parts of the ship have been dated with dendrochronology and the C-14-method to the last quarter of the 13th century AD. Some parts and materials, like animal hair caulking, might be older or contaminated somehow. A whetstone and early medieval ceramics were found in underwater archaeological excavations (Mökkönen 2006, 40–44; Wessman 2007, 141–142).

Two textile fragments SMM 2592:8 (c. 10 x 25 cm) and SMM 1393:27 (c. 4 x 8 cm) were found placed in between the wooden planks. Nail holes were present in both of the fragments. This might be a secondary deposit of the textiles. The fragments were woven in 2/1 twill, using very tightly z-spun yarns (warp?) in one system and Sz-plied (weft?) in another. Due to the strong similarity in the yarns and the thread counts, the fragments are probably from a single textile. The fragment SMM 2592:8 has been repaired with darning stitches during its time of use. The course of the reddish darning yarn does not follow the shed, but rather only imitates a twill structure (Vajanto 2013). The fragments are here examined to explain the clearly visible, distinct colours of the yarns and the original purpose of the textile.

2.2 The Egelskär wreck

The badly destroyed *Egelskär* wreck is situated in the Archipelago Sea. Her departure or target harbours are unknown. However, she was not sailing in unpopulated territories, because there is evidence of Medieval (1150/1300–1550 AD) and even earlier inhabitation on the largest islands of the Archipelago sea (Edgren 1977; Tuovinen 1990 and 2002). Perhaps she was lost from the fairway, which is described in the so-called *Danish Itinerary*, written in the 13th century (Edgren 1995). That route follows the coast of Finland from Sweden to Estonia (Gallén 1993; Dahlström 1966) and presents the safe harbours and distances between them.

The *Egelskär* wreck is clinker built and lies in shallow water. The surviving part of the keel is c. 8 m. She had cargo of stoneware ceramics that has been dated to the early 14th century AD. In addition, she was carrying a bronze church bell, whetstones and a barrel full of iron bars (Wessman 2007, 142–144). The iron bars were covered with fibre material, which was identified to be sheep wool (Wessman 2007; Vajanto 2013). The fibres were examined in order to find any dyestuffs that could explain the sample's distinct orange shade of colour.

2.3. The Mulan wreck

The *Mulan* wreck (12 x 4.7 m) was found in the Gulf of Finland, near the Hanko peninsula, that was a natural harbour well known in medieval times (Niitemaa 1964, 22). She is made mostly of pine, but the exact type is unknown. She was probably wrecked shortly after the year 1611 AD according to a Dutch coin find and a dendrochronological analysis. This ship had various cargo items: bricks, two church bells with Cyrillic inscriptions, wooden vessels, tiles, guns and gunpowder. The cargo might have been the spoils of war, originally from Russia and the ship was possibly headed to Sweden (Vaheri 1996, 48–49).

The researched textile SMM 1494:21 was found near the rudder. The textile is c. 89 cm^2 in size, but in several pieces. The fragments may have originally formed a square textile, because there is a corner present. The visible shade of colour of the fragments is reddish. The colour and the purpose of the textile are here studied more closely.

2.4 The wreck of the Sankt Michel

The best sailing season in the Finnish waters is and has been during the summer time in the period of the so-called white nights. During the winter and early spring, sailing is not possible because of the sea ice covering. The desire for profit and gain made the captains try to sail as late as possible in autumn despite storms and shortening days with increasing darkness. This probably explains why the *Sankt Michel* sank to the Sea of the Archipelago in late October in 1747 on her way to Saint Petersburg (Rigsarkivet, Copenhagen, Denmark. The Sound Toll Registers. Østend customs accounts: 15 October 1747, RaDk).

The *Sankt Michel* (25 x 7 m) had a valuable cargo consisting of cotton fabrics, sewing thread, Meissen porcelain, a horse chariot, and small luxury items such as pocket watches and snuffboxes (Alvik 2012, 108–132; RaDk, The Sound Toll register 15 Oct. 1747). The largest Finnish shipwreck textile, a rococo petticoat (SMM 62001:127), is from the *Sankt Michel*. The bones of a young woman were excavated from the wreck, but it is unknown, whether this was her petticoat. The petticoat is c. 300 centimetres long and c. 100 centimetres wide. This fabric consists of two layers of silk with batting made of wool. The silk was decorated with floral patterned quilting using silk thread and silver pearls (Pylkkänen 1982, 67; Ehanti 2012, 63). For this paper, the fibre material of the petticoat's batting was taken for closer examination.

In addition, there are textiles from a luggage chest including a ball of wool yarn, the remains of a possible hat, several pairs of wool socks and a fragment of a silk sock made in Nimes, France (Pylkkänen 1982, 334; Vajanto 2012a, 135–136). The wool sock SMM 62001:120 is perfectly preserved. It is c. 70 centimetres long from heel to knee and c. 26 centimetres from heel to toe. A sample from the sock was taken for this study in order to determine the condition of the fibres and any new information that could be obtained from a find that was excavated decades ago.

2.5 The wreck of the Vrouw Maria

Before the invention of modern navigational equipment, navigation was done visually by following known landmarks. The demanding environment and errors in navigation explain why the *Vrouw Maria* (26 x 7 m) sank to the Archipelago Sea in a storm in late September in 1771 on her way to Saint Petersburg (Ahlström 2005, 98). She was loaded in the port of Amsterdam with over twelve thousand kilograms of precious dyestuffs and mordants, cotton and wool fabrics, coffee beans, porcelain and small luxury items, and famous paintings for the empress Catherine the Great of Russia (Gelderblom 2003; Rigsarkivet, Copenhagen, Denmark. The Sound Toll Registers. Østend customs accounts: 23 September 1771; Vajanto 2012b).

Part of the textiles and dyestuffs were salvaged right after the shipwreck (Riksarkivet, Stockholm. *Inkomna handlingar, Kabinettet, RA. Huvudserie*. E 1 A:11 (vol 11), but part of the material is still *in situ* in the cargo hold in the original wooden package boxes (Vajanto and Alvik 2011). Two textile samples from the *Vrouw Maria* were studied for this paper. The first one is 1 x 1 cm in size and excavated from the wreck in 2011 (Vajanto 2012a, 134). The latter sample is 1.5 x 2 cm in size, excavated in 2012. These are both only tiny samples of a large, but fragmented textile material that is still *in situ* in the wreck.

3. Methods

In Finland, invasive research permission is granted by the National Board of Antiquities only if the research methods are well known and trusted. The aim is to preserve the finds as intact as possible for the future generations. Therefore, the traditional textile archaeological methods i.e., visual analysis and micro-destructive methods with a small sample size, were selected for this study.

3.1 Microscopic analyses

The study of the archaeological textile finds was begun with visual analysis using a stereoscopic microscope and digital photographs. The size of the item, structures, the twist direction and the diameter of the yarns, the thread count per centimetre were determined as well as the spinning and plying angles.

Fibre identification was made with a transmitted light microscope by observing morphological features and by measuring the diameter of the fibres. In order to ensure that the observations made with the transmitted light microscope were correct, the fibres were pictures at Aalto University School of Science, Department of Applied Physics with a scanning electron microscope (SEM). The type of the device was JEOL JSM-7500F, the acceleration voltage was 2 kV, and the working distance c. 15 millimetres. The secondary electrons were collected with a detector of the Everhart-Thornley type, situated at the side wall of the research chamber. The samples were placed on aluminium planchets with double-sided carbon tape and coated with gold.

3.2 Wool type analysis (fibre analysis)

Wool type analysis groups different types of wools (Nahlik, 1963; Ryder 1974). It is known from archaeological record, that white and homogenous wool existed commonly in the Mediterranean area already 2000 years ago, but they did not arrive to northern Europe until hundreds of years later (Ryder 1974, 1978, 1983; Rast-Eicher 2008; Bender-Jørgensen and Walton 1986). In southern Europe, a Merino type of soft and white wool existed already in the 13th century (Lipson 1953, 37; Ryder 1987). In Finland, the double-coated wool has been found from the late Iron Age and early medieval samples (Kirjavainen 2005a, 2005b; Vajanto 2013). At the beginning of the 20th century there were serious attempts to evolve the Finnsheep's wool from primitive double-coated to soft and homogenous (Vohlonen 1919 and 1927).

The wool type analysis has been seen as a useful tool to determine the provenance of wool (Maik 1990, 122). This method has been criticised for fitting poorly to sorted wool that is often present in the yarns made of the primitive kind of wool (Christiansen 2004, 11–18; Rast-Eicher 2008, 153–155). Nevertheless, fibre analysis is a simple, but practical tool for grouping different fibre distributions of the yarns. The wool classes are Hairy, Hairy Medium, Medium, Generalised medium, Medium, Semi fine, Fine/Generalized medium and Fine (Walton 2004, 83).

In the fibre analysis, the diameters of the fibres are measured and the proportion of medullated fibres is counted from the population of at least of 100 fibres (Ryder 2000: 4). If possible, the warp and weft yarns should be analysed separately. It has been suggested that even 50 fibres would be sufficient (Kirjavainen 2005a, 135; Kirjavainen and Riikonen 2007, 135). This protocol with a smaller count could possibly fit to highly degraded material with a few measurable fibres. In this study, the fragment from Mulan contained quite degraded and partly mineralised fibres, and it was not possible to find a group of 100 fully preserved fibres from the sampled yarn. In this particular case, the warp and the weft were measured as a single population.

3.3 FTIR, XRF and HPLC analyses

X-ray fluorescence (XRF) and Fourier transform infrared (FTIR) analyses have been only rarely applied to Finnish archaeological textile research, and these methods were used in this study as an experimental approach. These analyses were done at the Metropolia University of the Applied Sciences of Finland, where these methods have been applied constantly in textile conservation. In the XRF analysis the elements of the samples were measured with a small portable device, the Innov-x (alpha series) using the standard modes to gather additional data to explain the visible shade of colour observed in the fibres from the *Egelskär* and *Lapuri* wrecks. The FTIR analysis was done using Nicolet spectrum 100 to identify chemical compounds of the heavily degraded fibres found in the textile sample from the *Vrouw Maria*.

Table 1. Main elements of the yarns of the *Lapuri* SMM 2592:8 and SMM 1393:27 samples.

Find	Yarn	Fe (ppm)	S (ppm)	Ca (ppm)
Lapuri, SMM 2592:8	warp	7290.51	259041.38	4739.42
Lapuri, SMM 1393:27	weft	20039.13	579162.19	9986.45
Lapuri, SMM 2592:8	darnings	-	840559.75	-

Samples sized 2–5 millimetres were taken from textile finds from the *Lapuri*, *Egelskär* and *Mulan* wrecks and sent for dye analysis to the Royal Institute for Cultural Heritage KIK/IRPA, Belgium. The analyses were carried out by researcher Ina Vanden Berghe with High Performance Liquid Chromatography (HPLC-DAD) following the normal extraction protocol for this method. In a HPLC analysis a negative result does not necessarily mean an undyed textile, but that the sample size has been too small or the material too mineralised. Additionally, a positive result can indicate either a true dye or contamination.

4. Results

4.1 Twill from the Lapuri wreck

The warp and weft yarns contain a primitive type of wool, which has previously been defined as Hairy medium/Generalised medium type (Vajanto 2013). This kind of wool contains fibres from both the soft underwool and the coarse outer coat hairs (Ryder 2000). The darning yarn has been spun from a naturally pigmented, brown Medium type of wool (Vajanto 2013).

The diameter of the z-twisted warp (SMM 1393:27) is one millimetre and the spinning angle c. 45–55°. The weft (SMM 2592:8) is also 1 millimetre in diameter, but spun with an angle of c. 45°, and plied with an angle of c. 45–65°. There are 10 ply twists per centimetre. The darning yarn had a spinning angle of c. 20°. There seemed to be two parallel darning yarns as a pair, or the darning yarn had been plied very loosely.

The z-spun yarn from warp (SMM 1393:27) and the tightly Sz-plied weft (SMM 2592:8) are dark, while the thick z-spun darning yarn (SMM 2592:8) is reddish. The HPLC-DAD analysis revealed ellagic acid, i.e., tannin from all the yarns (Vanden Berghe 2012, 12). The XRF found high proportions of iron (Fe) from the warp and the weft, when measured with the so-called soil mode. This mode sees not only the metal elements, but also some of the lighter elements. The darning yarn contained no iron at all, but sulphur (S) as main element. (Table 1)

4.2 Fleece from the Egelskär wreck

The fibre material of the SMM 342006:16 fragment is sheep wool (Vajanto 2013). The fibres are in good condition and the identification was based on the visual analysis of the scale pattern. The wool has previously been determined as Hairy type, with mostly white fibres (Vajanto 2013). There are no textile structures visible, that suggest the find as sheepskin.

In general, the fibres are deep orange in colour (Fig. 1). In the HPCL analysis, no organic dye compounds were found (Vanden Berghe 2012, 12). The XRF measurement (alloy mode) revealed that the sample contained iron as the main element (Fe 99.49%) and small quantities of tin (Si 0.51%).

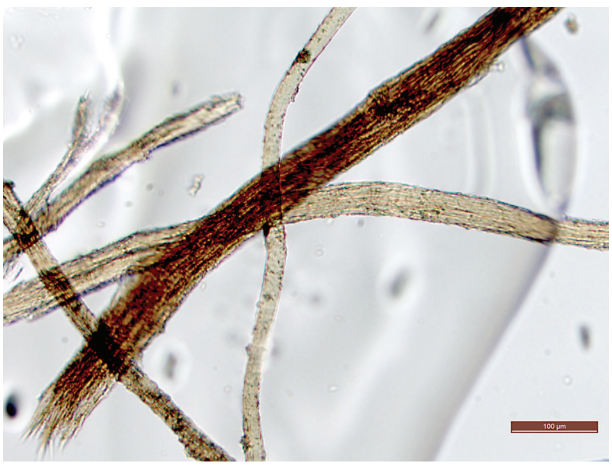


Fig. 1. Orange fibres from the fragment SMM 342006:16 from the *Egelskär* wreck. Photo: K. Vajanto.

Table 2. Statistical data of the wool analyses.

Find	Count of fibres	Median (µm)	Average (µm)	Standard deviation	Mode (µm)	Variance	Medullated (100 %)	Pigmented (100 %)	Wool Type
Mulan SMM 1494:21	103	21.00	24.29	10.51	18	111	12	2	Generalized medium
Sankt Michel SMM 62001:127	127	42.90	45.92	28.41	12	807	25	52	Hairy
Sankt Michel SMM 62001:120	110	24.00	24.54	3.92	24	15	0	0	Fine

Most likely, the orange colouring is rust, i.e., iron oxide, and contamination from the archaeological context.

4.3. Tabby from the Mulan wreck

The fragment SMM 1494:21 has been woven in plain weave using s-spun yarn one and z-spun in other yarn system. The thread count is 12/12 per centimetre. The diameter of the yarns is 0.7–1 millimetres and the spinning angle 45°. The disorder of the fibres on the fabric's surface might refer to after-weave treating, like fulling or use marks of wearing.

The material of this fragment consisted mostly of white sheep wool (Tables 2 and 3). The average fibre diameter was found to be 24 µm, the range from 10 to 55 µm and the proportion of the medullated fibres was 12%. In HPLC analysis no organic dyes were found (Vanden Berghe 2012, 12), that might refer to an originally white textile.

4.4 Textiles from the Sankt Michel

The silk fabric of the petticoat SMM 62001:127 is badly deteriorated and the dark woollen batting clearly visible. The quilting with a floral pattern consists only of needle stitch rows in the wool batting and the silken sewing thread has mostly vanished. The analysed silk fibres had a pinkish orange hue. The sample from the batting contained naturally pigmented (black and brown) fibres with only a few white fibres. The original colour of the fibres is difficult to determine, because some of the fibres had bluish and brownish shades and might have been dyed. In general, the sample contained both very thin and very thick sheep wool fibres (Fig. 2). The thickest fibres were medullated and even 120 µm in diameter; the thinnest was only 8 µm in diameter (Tables 2 and 4).

The material of the sock SMM 62001:120 is sheep wool. The diameter of the Sz-plied yarn is 0.5 centimetres and spinning angle 20–30°. The sock has been knitted with the stockinette stitch c. 11 loops and 9 rows per centimetre. Carefully knitted decreases at the ankle area are typical to the socks from that period (Pylkkänen 1982, 333–337). The average fibre diameter in the sock was 24 µm and the diameter distribution from 16 to 34 µm. All fibres were unpigmented and no medullated fibres were present (Tables 2 and 5).

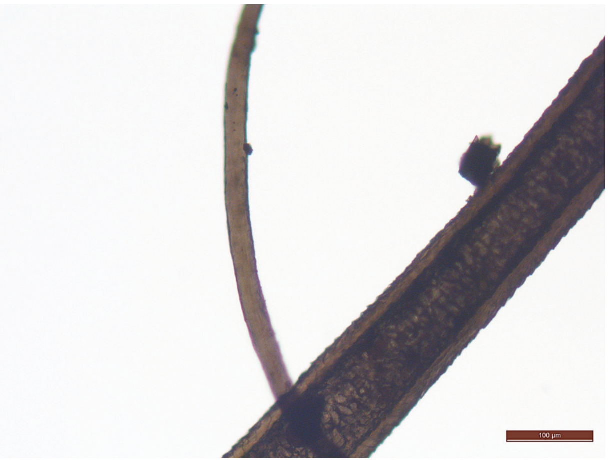


Fig. 2. Dark sheep wool from the batting of the petticoat SMM 62001:127 from the *Sankt Michel*. Photo: K. Vajanto.

Table 3. Wool analysis of the sample SMM 1494:21 from the *Mulan* wreck.

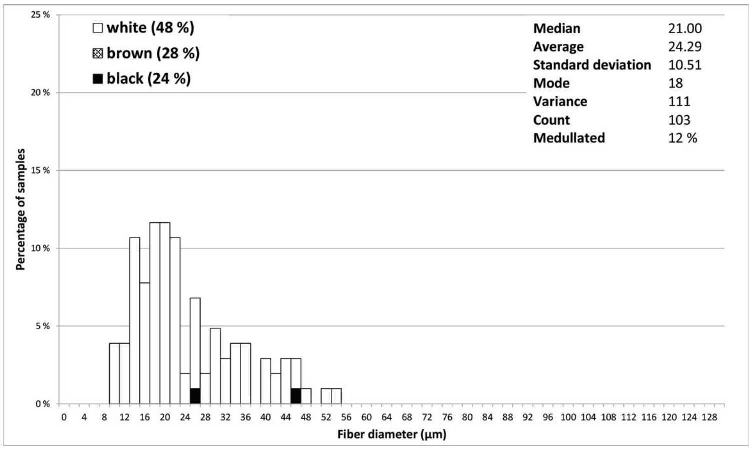


Table 4. Wool analysis of the batting of the petticoat SMM 62001:127 from the *Sankt Michel*.

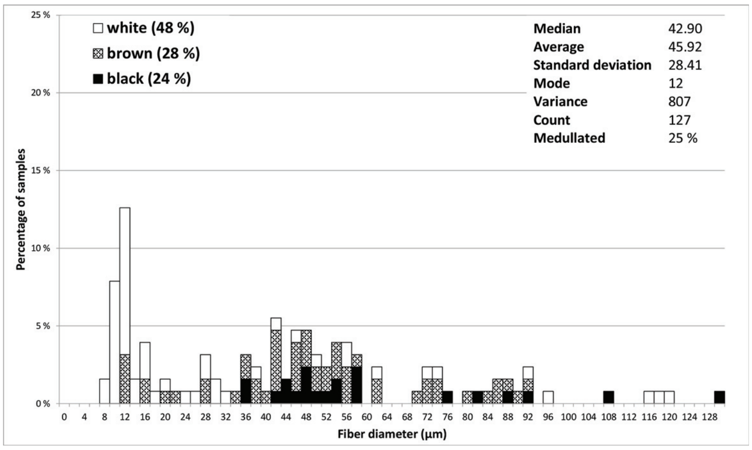
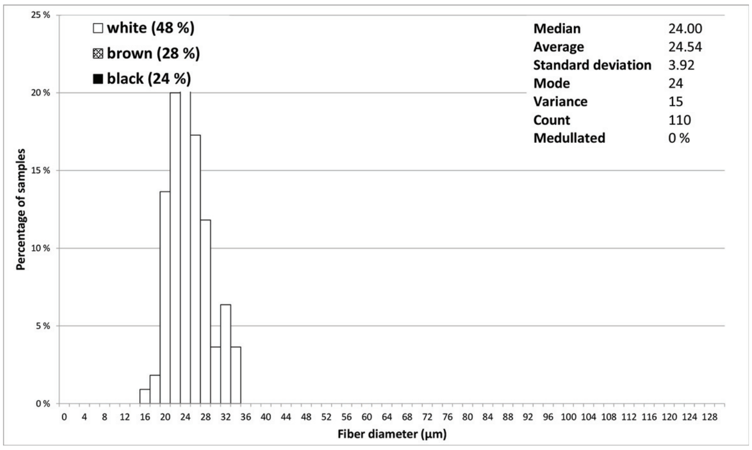


Table 5. Wool analysis of sock SMM 62001:120 from the *Sankt Michel*.



4.5 Fragments from the Vrouw Maria

The fragments from the *Vrouw Maria* are warp-faced tabby weave. The warp is z-spun and has a spin angle of 45°, while the weft is very loosely s-spun. The thread count in the warp is 14 yarns per centimetre and in the weft 6 yarns per centimetre. The yarn diameter is consequently 0.5–1 and 1–2 millimetres. The fibres are in parallel position that refers to combed fibre material (Forbes 1987, 21) and a worsted yarn (Heaton 1965, 262–263).

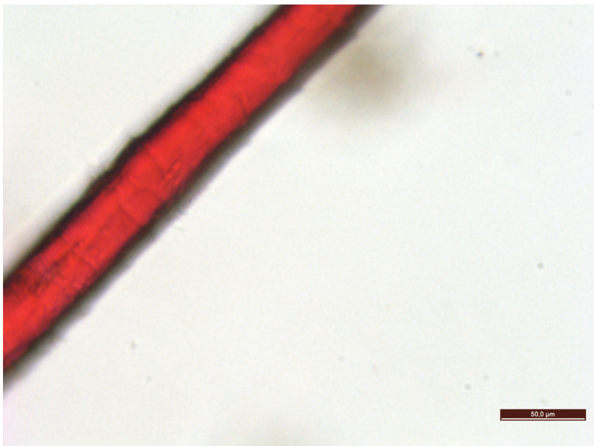


Fig. 3. Red and lustrous wool fibre from the *Vrouw Maria* fragment. Photo: K. Vajanto.

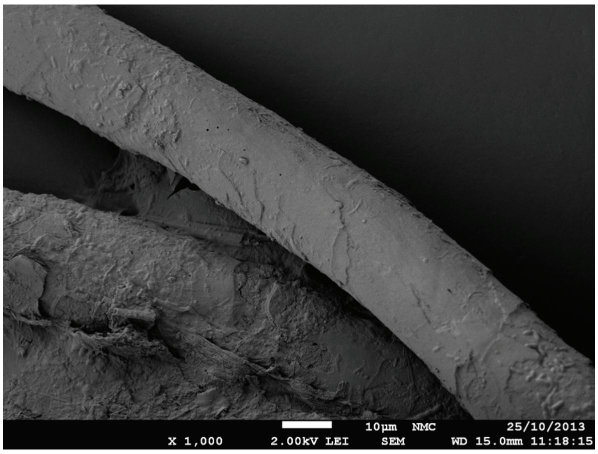


Fig. 4. SEM image of the mohair fibres from the *Vrouw Maria* fragment. Photo: A. Nykänen.

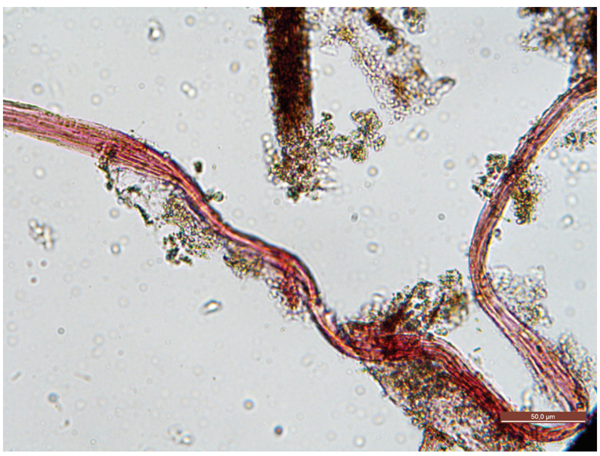


Fig. 5. Cotton fibre from the *Vrouw Maria* fragment. Photo: K. Vajanto.

The sample from the warp yarns contained deeply red, shiny fibres that had barely visible scales with long scale distance and a diameter of 18–20 µm (Fig. 3). In addition, there were thin, light pink fibres (8 µm) of possible white sheep wool. The "polished" feature of the deeply red fibres with shallow scales is typical to the mohair wool of the Angora goat (Appleyard 1978, 2). This observation was ensured with SEM images, in which the surface morphology of the fibre was found to be indeed more close to mohair than sheep wool (Fig. 4).

Most of the weft consisted of highly degraded fibres that had a pink-lilac shade of colour. The diameter of these fibres was 25–30 µm and there were no scales, but faint vertical lines (Fig. 5). The identification was not possible to do with the transmitted light microscope, because the degrading of fibres in the seawater changes the morphological features (Chen and Jakes 2001). In addition, the weft contained a few animal fibres that were c. 5–10 µm in diameter. These were possibly sheep wool, because there was not such a shine as was present in the thicker fibres of the warp yarn. A FTIR analysis indicated that both protein and celluloid material are present in the weft yarn (Fig. 6). The cellulose peak is similar in other plant fibres too, and FTIR is not adequate for the identification of the plant species. With the scanning electron microscope (SEM) an end of a flat and twisted fibre was found and the fibre was identified as cotton (Fig. 7).

The surface of the textile fragment was soft. The suspected mohair fibres of the warp covered the surface all over forming a nap. The nap is not cut, but possibly fulled (Fig. 8). Additional findings from the sample were silk fibres that formed a textile-like structure (Fig. 9). A plant fibre might be nettle (Fig. 10), because of a bulb formation (Karttila 2012, 24). It is known, that nettle fabrics were a part of the *Vrouw Maria*'s cargo (*Riksarkivet, Stockholm. Inkomna handlingar, Kabinettet, RA. Huvudserie*. E 1 A:11 (vol 11). These fibres are possibly not connected to the red broadcloth fabric at all and perhaps the excavations in the future will explain these random findings.

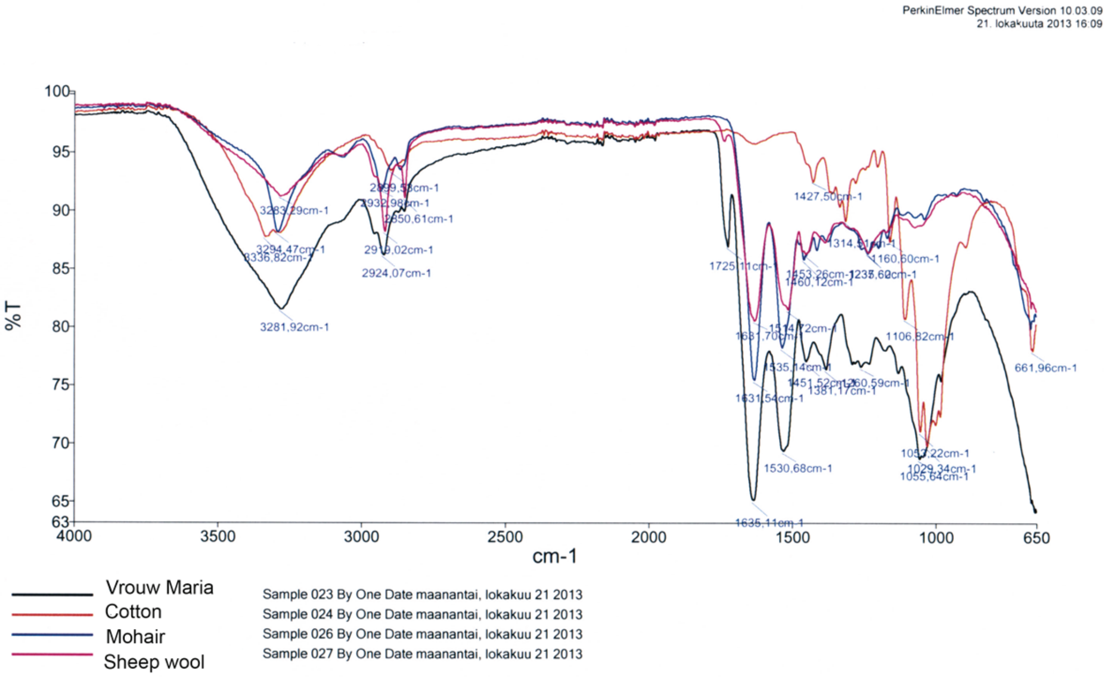


Fig. 6. FTIR spectrum from the weft yarn of the *Vrouw Maria* fragment with cotton, sheep wool and mohair references.

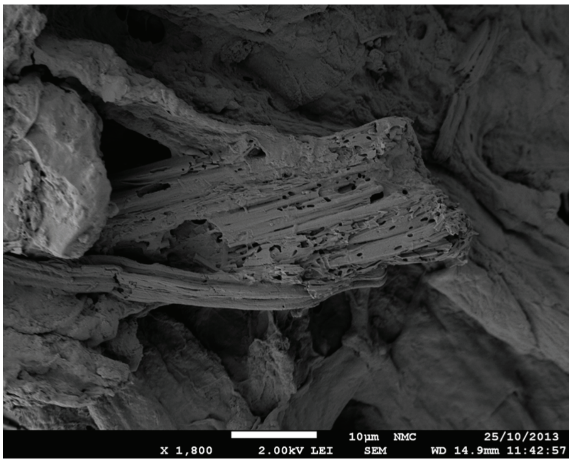


Fig. 7. SEM picture of the cotton fibre from the *Vrouw Maria* fragment. Photo: A. Nykänen.

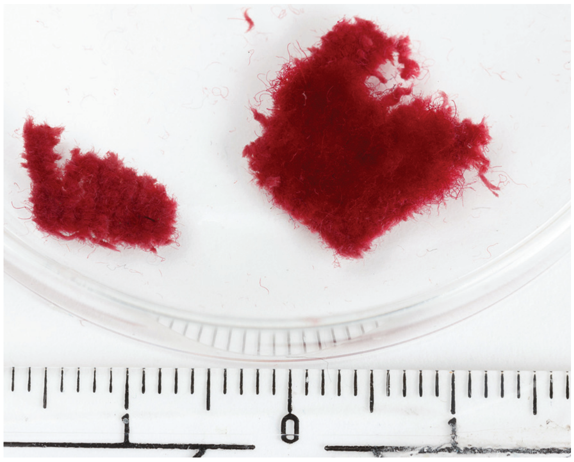


Fig. 8. The Vrouw Maria fragment. Courtesy of Riikka Alvik, National Board of Antiquities, Finland.

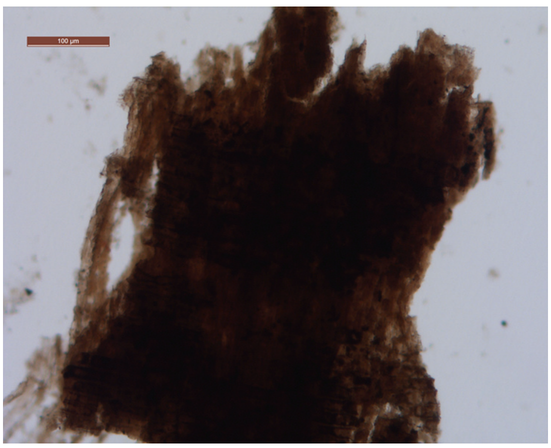


Fig. 9. Possible silk textile fragment from the *Vrouw Maria*. Photo: K. Vajanto.

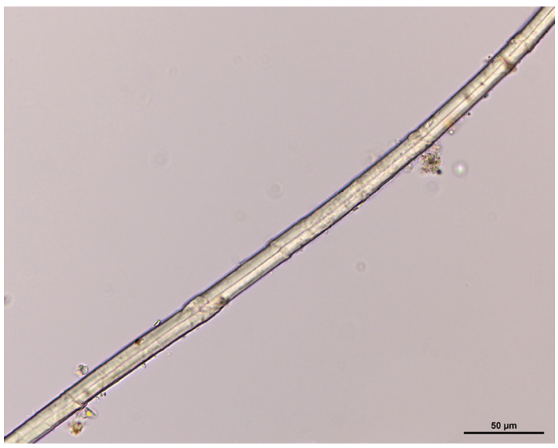


Fig. 10. Possible nettle fibre from the *Vrouw Maria*. Photo: K. Vajanto.

5. Discussion

5.1 A woollen sail from the Lapuri wreck?

It is known that iron (Fe), sulphur (S) and tannin accumulate naturally to underwater material (Fors 2008). Thus, the iron and sulphur found in the XRF measurements as well as the tannin found in the HPLC analysis might be contamination from the marine environment. To make the interpretation more complicated, the accumulation seems to be irregular; the finds from the *Egelskär* and the *Mulan* wrecks contained no tannins at all. In the case of the *Lapuri* fragments, the HPLC-detected tannin might be from the wreck itself, or it could be a dye or natural tannin mordant, that works well for wool (Vajanto 2010).

Usually the plied yarn of a textile is in the warp, but in the *Lapuri* fragments the unplied yarns formed a more regular order of the yarns. This feature is more natural to warp than weft, at least if there had been a reed directing the warp yarns. The use of plied yarn in the weft is understandable, if there has been a very large fabric in process. With the thicker weft yarns, it is possible to increase the length of fabric faster than when using thin yarns. The tight spin and ply and the long outer coat fibres add the breaking resistance of the yarn (Vajanto 2013, Vajanto in this publication).

With visual observation, the warp and weft yarns differed remarkably from the darning yarn made of reddish wool. The XRF measurements conformed to this, which suggest that the iron is not an accumulation product. The difference could be explained with a purposeful adding of iron to the newly woven fabric. The darning stitches were possibly done during a different event.

Experimental archaeology has proven that 2/1 woven sail works well in square-rigged boats (Andersen and Nordgård 2009). It is known from historical sources that woollen sails were woven in Scandinavia with 2/1 twill (Cooke et al. 2002). There is folklore knowledge wisdom about woollen sails that were *smörred*, which means that they were treated with a mixture of animal grease and red ochre (Cooke et. al. 2002, 205). Perhaps the *Lapuri* textile fragments once belonged to a *smörred* woollen sail, a fabric with a high tenacity. The original colour of the textile might have been reddish due to red ochre pigment. Brown wool was perhaps selected to the darning yarn on purpose just to fit to the colour of the reddish *smörred* fabric.

5.2 Sheep wool products

The examined shipwreck textiles were made of several kinds of sheep's wools. The wools from the *Lapuri* and the *Egelskär* wrecks were of double coated sheep (Vajanto 2013) and this conforms to what is known about the late Iron Age and early medieval wools found in Finland (Kirjavainen 2005a, 2005b; Ryder 1978).

The fragment from the *Mulan* wreck was possibly undyed and woven from naturally white Generalized medium wool. The fibre distribution is close to the wool from the English sheep found in Medieval Gdansk, Poland (Maik 1990, 123). The material from Gdansk might indicate the preferred quality of wool garments at the coasts of the Baltic Sea during the 17th century. The s- and z-spun yarns had originally formed a surface with en even shine. Maybe this textile fragment is from a flag, which could explain the square form and the tight weave structure.

A hairy type of wool was found from the batting of the rococo petticoat from the *Sankt Michel*. The coarse wool creates a crude contrast to the beautifully quilted silk. It is difficult to explain why this type of wool was used inside the fine silk fabrics. It is worth noting that the coarse wool was not visible at all in position between two silk layers and thus the coarse wool may have been selected in order to decrease the cost of the precious petticoat.

The sock from the *Sankt Michel* was made of Fine wool, which is a product of a Merino sheep (Ryder 1987). During the 18th century, Merinos were bred in Spain, England and France (Lipson 1953, 36–45; Philippes 1997), but the Merino wool had been traded during several centuries (Lloyd 1977; Munro 1972). Because of its role in a long run trade article, the origin of the sock's wool cannot be determined. The Merino wool is so soft that it rarely causes any itching and without doubt has felt pleasant on the feet. However, this soft wool does not stand wearing as well as the coarser wools do. Perhaps this sock was a luxury item and not knitted for a peasant's feet.

5.3 Tracing the dyes

Before the invention of the synthetic dyes at the end of 19th century, the textiles were dyed with natural dyes. The red dyes came mainly from madder (*Rubia tinctorium*), orchil lichens (*Orcholecia* and *Rocella* species), redwood (*Cesalpinia* species) and insect dyes (kermes and cochineal species), the blue from indigo plants and the yellow mainly from weld (Cardon 2007; Schweppe 1993). When the dating of the shipwreck textiles is taken into consideration, it is quite clear, that these textiles have been dyed with natural dyes.

The shade of colour in the fibres from the *Vrouw Mari*a was very even and the original colour of the warp and weft might have been equal. This can refer to the dyeing of the fibres before spinning. The fibre types differ from each other only by the lightness: the wool fibres have more intensity and the cotton fibres are lighter in colour. The colour difference might be a result of ageing of the fibres since the different fibre types most likely have degraded at a different rate.

In addition, we might be dealing here with two different dyeing methods. Wool as a protein fibre stands better acidic dye baths and mordant dyes, but cotton as a cellulose fibre stands also alkaline dye baths. For example, orchil produces quite a similar shade of colour as cochineal, but the latter was far more expensive. The cheaper dyestuff would have been an excellent choice for the invisible weft of the warp-faced textile. However, the dyes can be ensured only with accurate additional HPLC analyses, which possibly will be done in the future.

The sock from the *Sankt Michel* contained light pink wool and the degraded silk fibres of the petticoat were pinkish orange. The colour of these fibres is close to insect dyes as well as redwood, but again, this is only a visual estimation and should be confirmed with HPLC tests. Anyhow, the fibres were so constantly colourful that they are probably from dyed textiles. The original shades of colour might have been more intense, and faded during the centuries in seawater. The brownish tint of some wool fibres of the petticoat's batting might be contamination from the submerged position. The opened scales and the bluish tint could refer to an alkaline dyeing process with indigo that stresses the fibres (Balfour-Paul 2011, 116–117, 129–130; Cardon 2007: 345–352).

5.4 Camlet from the Vrouw Maria?

The shiny fibres of the *Vrouw Maria* fragments are reminiscent of the mohair wool of an Angora goat, underwool of camel, and wool of Cashmere goat (Appleyard 1978, 33–32, 41–45). Camel and Cashmere fibres have been used for fabrics for centuries (Forbes 1987, 63; Grömer 2010, 65), but are difficult to distinguish from the sheep wool (Bergman et al. 1975, 10–11 and plates 2 and 4). The shallow scales, long scale distance and distinct lustre strongly speak here for the use of mohair fibres. The thin wool fibres in the warp and weft may be ultra-fine Merino wool.

A dictionary of trade and commerce written in the early 19th century reveals an interesting piece of information about the mohair goat's hairs. The mohair fibres were imported from the Near East to Europe, where high quality *camlets* or *camblets* fabrics were woven. These were woven in tabby weave. Some of the camlets had goat's hair in both warp and weft, some goat's hair in the warp and mixed goat's hair and silk in the weft, some sheep's wool in both yarn systems, while some had sheep's wool in the warp and "thread" in the weft. The "thread" was made of silk, flax or cotton (Mortimer 1810, 173, 613–614, 812, 1182).

Archaeologists have found a lead seal from the *Vrouw Maria*, dropped from a textile package with text "Leiden, Willem van Lelyweld" (Ehanti 2012, 63). During the 17th and 18th centuries Leiden was one of the most important centres of high quality fabric production and especially known for mixed-fibre textiles containing mohair, Merino wool as well as goat and camel wool (van der Ween

2003, 443, 450). This seal indicates that the *Vrouw Maria* had valuable Dutch cargo, but the connection of this particular researched fabric is of course uncertain. Interestingly this precious fabric was destined for Russia, which had prohibited the import of foreign fabrics in 1718 (van der Ween 2003, 452). Perhaps this camlet was bought for the Empress Catherine the Great herself, who might not have been subject to the consumption regulations.

6. Conclusions

Shipwreck textiles were researched to shed light on this little researched Finnish archaeological find group. The Finnish waters are full of shipwrecks, but only a few textile fragments have been found from the wrecks. The study revealed that not all supposed textiles are fabrics: the find from the *Egelskär* wreck was interpreted as remains of a sheepskin. No organic dyes were found in the HPLC analysis. The orange colour of the originally white fibres is probably iron oxide, i.e., rust from the iron bar cargo of the wreck. Indeed, in the XRF analysis, the iron (Fe) was found to be the main element of the find.

The *Lapur*i fragments were found to contain yarns spun from a primitive kind of wool. The z-twisted yarn was interpreted to be the warp, the Sz-plied yarn the weft and the loose z-spun a darning yarn. The primitive wool type, tight twist as well as the tight ply increases the breaking resistance of the yarns and the tenacity of the fabric. Tannin was found from the yarns in a HPLC analysis, but the finding was interpreted to be a contamination from the wreck itself. In the XRF analysis, the warp and weft were found to contain iron, but the darning yarn did not have any. The fragments were interpreted to be the remains of a *smörred* sail fabric that had been treated with red ochre. The reddish darning yarn had possibly been selected on purpose to match the red ochre treated textile.

The textile from the *Mulan* wreck was found to be made of white and unpigmented wool. It contained s- and z-spun yarns that had formed an even shine to the surface of the fabric. It was suggested that this textile was a fragment of a flag. The sock from the *Sankt Michel* was found to be spun from fine Merino wool. The white wool was probably dyed with pink and red natural dyes. This colourful soft wool textile was probably quite an expensive product and not meant for a peasant's foot.

The quilted petticoat from the *Sankt Mikael* had a dark and coarse batting made of Hairy wool. This batting had possibly been dyed with indigo, because the wool fibres had a bluish hue and the scales were opened. Perhaps this crude wool was selected to decrease the cost of the quilted petticoat due to its invisible placement within two silk layers.

The red fragments from the *Vrouw Mari*a consisted of several morphologically different fibres. Sheep wool, mohair, and cotton were found with the transmitted light microscope and in the control with the SEM images. The mohair fibres were present in the z-spun warp yarns. The loosely s-pun weft contained cotton and thin sheep wool fibres. Additional findings were a few possible nettle and silk fibres, which probably were not connected to the red fabric, but might be contamination from the other fabrics in the cargo. The red fibres were interpreted to be dyed before the spinning, possibly using two different dyeing methods for the different fibre types. The red textile was interpreted as an expensive, high quality camlet.

These unique finds from different time periods enrich our knowledge of shipwreck fabrics and garments found in the marine archaeological contexts in Finland. It is hoped that the underwater excavations in the future will reveal more textile finds, so that we could sharpen our picture of the trade and transport of fabrics on the maritime fairways of the Baltic Sea.

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