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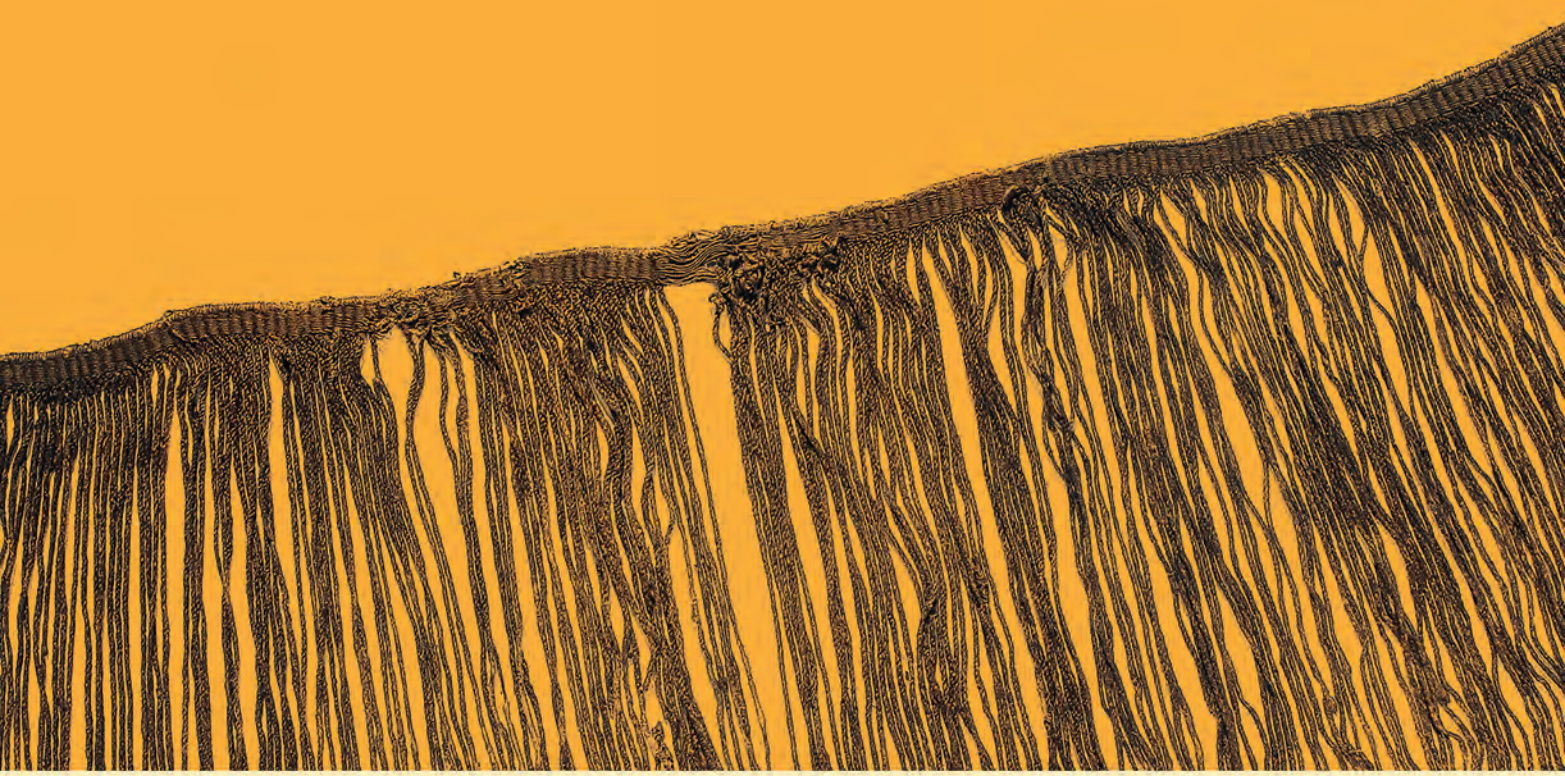
ARCHAEOLOGICAL TEXTILES REVIEW



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Conferences

Marianne Vedeler and Lena Hammarlund

Reconstructing the Tunic from Lendbreen in Norway

Abstract
A woven wool tunic with damaged sleeves and repairs to the body dating from AD 230 to AD 390 was discovered on the Lendbreen glacier in Oppland County, Norway in 2011. The Norwegian Mountain Centre in Lom (Norsk Fjellsenter) and the Museum of Cultural History at the University of Oslo each commissioned a reconstruction of the tunic for exhibition and research into prehistoric textile production. The original was woven in 2/2 diamond twill with differently coloured yarns producing a deliberate and even mottled effect. The reconstruction project investigated the materials required, the likely tools used and the weave, with new investigations into the processes of collecting, sorting, and spinning the wool, the thread system, the finishing treatment and sewing to produce two tunics as they might have been as new with complete sleeves and no repairs. Estimates for the labour required for each stage suggested a total of just over 402 hours per tunic.

Introduction

In August 2011, a group of archaeologists was searching the mountains on the Lendbreen glacier in Oppland County, Norway. The country's glaciers are melting, and objects that have been hidden under the ice and snow for thousands of years are now coming to light. On the mountainside, the archaeologists came across a crumpled piece of textile, which, when examined at the Museum of Cultural History in Oslo, turned out to be a tunic (fig. 1). The Lendbreen tunic is the oldest piece of clothing found in Norway and one of the few surviving garments from the 1st millennium AD. As snow patches and glaciers rapidly melt in mountainous areas worldwide, hundreds of archaeological finds have been emerging from the ice each year (Nesje et al. 2011, 2-3). Artefacts from different periods are found deposited in the ice patches, many of them made of organic material rarely preserved elsewhere. Ice patches often provide exceptionally good conservation conditions for textiles. The Lendbreen glacier is located approximately 1,900 m above sea level in an area which was used for hunting activity over a long period up to modern times. The wool tunic was left there between AD 230 and 390 (Vedeler & Bender Jørgensen 2013, 789, 792).

The tunic from Lendbreen

The chest of the tunic measures approximately 1.08 m and the length is c. 92 cm. By modern size standards, this would fit a slender man who is 1.70 m to 1.76 m tall. The tunic is relatively short and constructed from a simple pattern. It consists of a body section and sleeves. The main body section is in one piece. The sleeves are set in curved sleeve openings (fig. 2). The

Fig. 1. The tunic from Lendbreen in situ (Photo: Vivian Wangen, Museum of Cultural History UiO).

Fig. 2. Front of the tunic from Lendbreen (Image: Marianne Vedeler, Museum of Cultural History, UiO).

body piece has a seam on the wearer's left side and is folded on the right. The tunic has a straight boat neckline with a small, raised rim on the back edge. Simple folds are used both in the front and at the back of the neckline. The lower part of the tunic shows that it was a well-worn garment. It was repaired using two patches at the back. Both sleeves are partly torn off, and the remaining sections are narrow tubes.

The fabrics used for the body section and the sleeves of the tunic are both woven in 2/2 diamond twill, but of slightly different qualities and colours. The same fabrics are also used in the two patches. The sleeves are dark brown in colour. Due to uneven exposure to the sun, the surface colour of the body appears patchy, but closer examination reveals that the fabric is deliberately and evenly mottled. This effect is caused by the use of two light and two dark brown threads made of naturally pigmented wool alternating in one thread system (Rast-Eicher 2011, 1). In the other thread system, only the light yarn is used. While the dark yarns are generally z-twisted, the light yarns shift to s-twisted in some areas. The alternating colour pattern causes the diamond pattern to almost disappear. The diamond twill pattern is slightly irregular. The diagonal lines are reversed after 8 to 11 threads in one direction and after 12 to 30 threads in the other (Vedeler & Bender

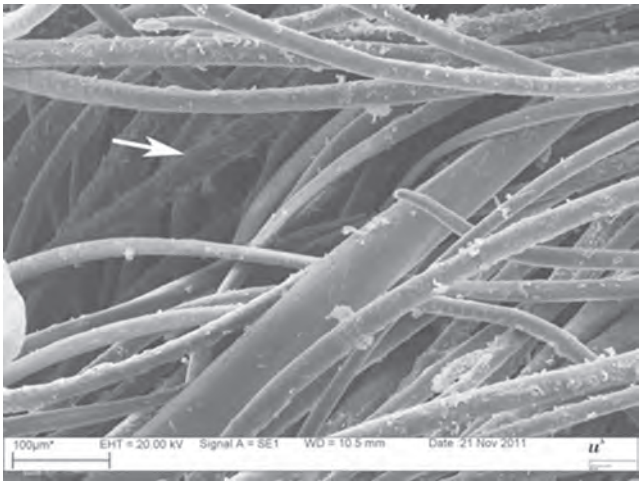

Fig. 3. The fibre thickness in the original tunic varies from fine to very coarse (Image: Antoinette Rast-Eicher, Archeotech).

Jørgensen 2013, 791). A narrow tablet-woven band attached to the side seam in the body is very difficult to investigate. The band is hidden inside the tunic and only visible from the reverse. Tablet-woven edges are quite common in Scandinavian Roman Iron Age textiles and appear to have been used both for starting borders and for selvedges (Schlabow 1976; Hald 1980; Ræder Knudsen 2011, 163-198).

The reconstruction

In spring 2016, the Museum of Cultural History at the University of Oslo and the Norwegian Mountain Centre in Lom (Norsk Fjellsenter) were planning two new exhibitions. The two museums decided to make reconstructions of the tunic from Lendbreen. The goal was twofold: the Norwegian Mountain Centre wanted a copy for exhibition purposes, the Museum of Cultural History (who had the original tunic in its collection) wanted to learn more about prehistoric textile production. During the reproduction process, the production time was measured in terms of labour hours used for the main stages: collecting, sorting, spinning, weaving, finishing treatment and sewing the wool.

The wool

The wool fibres in the Lendbreen tunic were examined using a scanning electron microscope and a light microscope. The fibre tips recorded during this analysis indicated that both fabrics were made of wool from lambs or plucked from an adult sheep with moulting properties (Rast-Eicher 2011, 1). Further, the fibre analysis showed a fibre diameter ranging from very fine (13 µm to 14 µm: from 0.5% to 2.7 % in all seven samples) to very coarse fibres measuring up to 98 µm (1% in one sample). An average of 68.3% of the fibres was below 25 µm (Rast-Eicher 2011, 7) (fig. 3). In the modern textile industry, fibres with a diameter of c. 25 µm and higher are considered to prickle and are not desirable in fabrics which touch the skin. The general fibre classification for modern Merino wool is fine: <20 µm, medium: 20-23 µm and strong: 23-25 µm (Robson & Ekarius 2011, 138).

Based on the above information, wool from Gamalnorsk sau – also called Villsau – was chosen for the reconstruction. This is a sheep belonging to the northern European short-tailed family. A double-coated fleece with fine wool and coarser hair are desirable properties for today's breed. The hair should not be too long, and not hang down on the sides of the body. The fleece should be dense, preferably with no parting on the backbone. The sheep moult annually (fig. 4) and live in harsh conditions outside all year around. Over-long hair would result in lumps of snow adhering to the fleece in the winter. The parting of the fleece at the spine results in warmth reduction in cold or wet weather (Norsk Villsaulag: Villsau).

The description of preferred properties from the Norwegian Villsau breeding society (Norsk Villsaulag) illustrates how sheep breeding is affected by climate and living conditions. The wool used for the reconstruction was collected from a flock at Aursneset on the west coast of Norway. The sheep graze outside all year and shed their wool naturally in the late spring. The wool from the sheep was rooed, that is, pulled off by hand (fig. 5). In the Lendbreen reconstruction project, it took less than 20 minutes for an experienced person to harvest the wool gently from one sheep and to do the initial rough sorting. On average, 1.5 kg of wool was collected from each sheep.

Prehistoric sheep fleece came in a variety of natural colours from white and grey to brown and almost black. The colour variations, not wanted in the modern textile industry, were used in the past for pattern building and decorative effects. Gamalnorsk sau has a large variety of natural fleece colours and to come as close as possible to the original tunic, a light beige and a dark brown naturally-coloured wools were selected. The sorting and fibre separation for the fleeces used in the reconstruction project was done by Ingvild Svorkmo Espelien at Selbu Spinneri. The coarsest parts were removed and the hair of the remaining fleece was separated by hand or with help of a broad wool/flax comb. After this process, too many short, coarse hairs and kemp fibres still remained in the material and had to be picked out by hand. In all, c. 90 hours were spent on the sorting and fibre separation process to produce enough wool for the reconstruction (fig. 6).

Fig. 4. The flock of Norwegian Villsau whose wool was used for the reconstruction project. The colours vary from light beige through brown and grey to almost black (Image: Marianne Vedeler, Museum of Cultural History, UiO).

Fig. 6. A sample showing different kind of fibres in the same staple: wool, hair and kemp fibres. The varied colours of the kemp fibres are a primitive feature (Image: Lena Hammarlund).

Fig. 5. Sheep farmer Alv Ottar Folkestad collecting wool from a sheep on the west coast of Norway (Image: Marianne Vedeler, Museum of Cultural History, UiO).

Fig. 7. The finished yarn is spun with a hard twist. A few pigmented coarser hair and kemp still remains in the light and well-separated fibre material (Image: Lena Hammarlund).

The spinning

The yarn in the original tunic was spun using a hand spindle, which is a very time-consuming process. Spinning has been considered a main bottleneck in textile production until recent times (Burnette 2008, 39-40). As time has become one of the most critical factors in today's production, some difficult choices had to be made during the reconstruction project. To reduce costs, the wool was machine-spun. This was done at a small spinning mill, Selbu Spinneri in Klæbu, Norway, where a yarn could be produced that closely resembled the original at a reasonable price (fig. 7).

At the same time, a spinning experiment was conducted: 10 hand-spinners from across Norway were given 50 g of the processed fibre material to spin a yarn with the same diameter and degree of twist as observed in the original tunic.1 On average, it took the spinners c. 11 hours to comb and spin 50 g of the wool, making an average amount of 292 m per 50 g. The spinners had very varied experience, and the time they used also varied significantly, from seven to 17.5 hours. From this, it can be concluded that, despite the careful sorting and preparation process, short hair, kemp fibres and small lumps still present in the wool made it difficult to spin an even yarn. About 2.5 kg of wool was used to make yarns for the reconstruction of two tunics. Based on the results of the spinning experiment, hand spinning the yarn for the reconstruction would have taken about 270 hours for one tunic or c. 540 hours for both.

Fig. 8. The reconstructed fabric was woven on a warp-weighted loom by Lena Hammarlund (Image: Marianne Vedeler, Museum of Cultural History, UiO).

The weaving and finishing treatment

Textiles dated to this period of the Iron Age are usually interpreted as having been woven on a warp-weighted loom. Loom weights and weaving swords are common artefacts in archaeological sites dating to the Iron Age in Norway and Denmark (Bender Jørgensen 1986, 140; Andersson 1996, 14). Finding preserved edges and weaving details in an archaeological textile can provide evidence of the loom type used (Ciszuk & Hammarlund 2008). A tablet-woven starting border, for instance, could indicate the use of a warp-weighted loom. An edge with visible small loops running along the lower front edge could be a starting or finishing border. This kind of edge with loops is found in Danish Iron Age textiles woven on a vertical two-beam loom by tubular warping with a warp-lock (Ciszuk forthcoming). In the reconstruction process, a weaving sample was made in this way, showing that it is possible to use such small loops as a starting or finishing border. On the other hand, the edge with small loops could be a simple selvedge. To conclude, it is not possible to know for sure what kind of loom was used originally, but based on the pattern in the archaeological find, it was decided to weave the fabrics for the reconstruction project on a warp-weighted loom (fig. 8). Further, when the original tunic was studied by Vedeler and Bender Jørgensen in 2013, it was not easy to establish the warp and weft directions in the fabric of the body. One aim of the reconstruction project was to look into this question again.

In the first publication of the Lendbreen tunic, the warp direction was interpreted as running vertically through the garment, giving stripes in the weft direction. This interpretation was made because a narrow tablet-woven band found on one side of the body was interpreted as a selvedge (Vedeler & Bender Jørgensen 2013, 791). Due to the difficult position of the tablet-woven band, it was not possible to study it any further. It is therefore still not possible to say whether the band was sewn on to or woven into the fabric, and thus, it cannot contribute further to the identification of the warp and weft directions.

The choice of twist direction, degree of twist and yarn diameter are also aspects that could provide clues about warp direction. However, the yarns in the body of the tunic all are spun with a z-twist with the same amount of twist and diameter in warp and weft. This means that no specific deductions can be drawn from these data. Neither the thread ratio for warp and weft in the tunic is of help in solving the question of warp and weft direction because these fall within the documented variants commonly used in the period (Hammarlund 2015). Other details such as gores and weft crossings could potentially be used to determine the warp and weft direction (Ciszuk forthcoming), but none has been identified in the tunic thus far.

More concrete features that could help in the identification of the warp and weft directions are the diamond twill pattern units. Technical analyses of archaeological textiles with diamond twill, where warp and weft directions are known, show that the majority of them has documented twill diagonal turns after an even number of threads in the warp direction, with 10 threads before the diagonal turns a typical number. In the weft direction, an uneven number often occurs, e. g. nine threads before the diagonal turns (Bender Jørgensen 1986, 194-204, 243-247). Choosing an even number of threads between the diagonal turns makes the heddling easier and more logical compared to uneven numbers. By using even numbers, two of the sheds can be easily picked up with the help of the starting border in which the threads run in pairs. This could be an argument for interpreting the fabric as having a striped warp.

Specifically in the chest area of the tunic a distinct stripe made of four light threads can be seen. It is broader than the other regular stripes made of two light and two dark threads. The broader stripe is possibly a weaving fault. Weaving experiments undertaken

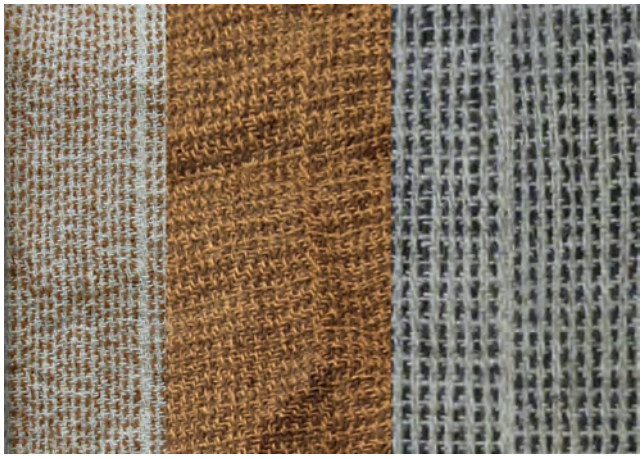

Fig. 9. A stripe of four threads woven in the warp direction appears different from a stripe woven in the weft direction. To the left the stripe is made in the weft, in the middle is the original and to the right the stripe woven in the warp direction (Image: Lena Hammarlund and Marianne Vedeler).

during the reconstruction process showed that this stripe appears differently depending on whether it occurs in the warp or weft direction. This is due to the colour effect combined with the diamond twill pattern weave. In comparison with the original, the visual appearance of that with the stripe woven in the warp is closer to the original than that woven in the weft (fig. 9). When making the stripes in the warp direction, the edge with small loops can be interpreted as a simple selvedge. This also means that the heddling follows the easier and more logical working process for making diamond twill reverses in the warp with an even number of threads between the diagonal turns.

The warp direction in the textile used for the body of the original tunic is still very difficult to determine, but the visual appearance of the weaving fault and the diamond twill pattern indicate that the mottled fabric was woven with a striped warp, not a striped weft, as suggested by Vedeler and Bender Jørgensen in 2013. The weave was reconstructed with a striped warp.

In the dark brown fabric used for the sleeves, no edges or other details were documented that could help to establish warp and weft direction. For this fabric, it was decided to follow the same principle for heddling as used in the mottled fabric for the body, with an even number of threads between the diagonal threads.

The surface of the original tunic shows no traces of finishing treatments. There were, however, traces of felted fibres inside the seams which indicate some kind of finishing treatment such as fulling. This phenomenon of hidden felted fibres can also be seen in textiles from the Thorsberg find (Möller-Wiering 2011, 63-64). Because of the traces of felted fibres, the reconstructed cloth was lightly fulled. This finishing treatment was used to smooth tensions and irregularities in the fabric (fig. 10).

Fig. 10. The finished fabric ready for sewing. The top fabric is the one made for the sleeves , while the fabric underneath is for the body part of the reconstructed tunic (Image: Marianne Vedeler, Museum of Cultural History, UiO).

The reconstructed mottled body cloth measured 1.25 m x 3.35 m when taken from the loom. The weaving and finishing treatment of the mottled cloth took approximately 104 hours. A total of 67 hours was needed for the weaving itself, to insert the weft, change the shed and beat the weft. Approximately 2 cm to 2.5 cm were woven per hour, using 20 wefts or 8.5 wefts per cm. The finishing treatment, including fulling by foot and stretching during drying, took approximately three hours. For the dark brown fabric used for the sleeves, measuring c. 0.55 m x 2.50 m, the weaving and finishing treatment took 52.5 hours of which 35 were used for the weaving. For this fabric, c. 3 cm to 4 cm were woven per hour, using c. 50 wefts or 13.5 wefts per cm. The difference in weaving time between the two fabrics is partly due to one being wider than the other. The mottled fabric measured c. 125 cm on the loom and the dark brown only 55 cm. Another difference is due to the warp set, with 11 to 12 warp threads per cm in the mottled fabric and 9 to 10 warp threads per cm in the dark brown fabric. The denser warp set makes the sheds harder to change and because of this the weaving took a bit longer.

The sewing

The original tunic from Lendbreen has a simple pattern consisting of three pieces of cloth: a body in one piece and two sleeves, each made from only one piece of cloth. In addition to this, two patches had been added at the back for repair. Four different types of stitches were used to form the garment: running stitch, casting stitch, blanket stitch and a so-called Thorsberger seam, where two pieces of cloth were first folded to each side and then the four layers of fabric joined by a seam of running stitches locking the tears (Vedeler & Bender Jørgensen 2013, 299) (fig. 11). The sleeves were set into rounded sleeve openings which were already locked with a double hem (Vedeler & Bender Jørgensen 2013, 293).

When reconstructing a prehistoric object, it is necessary to make a number of choices. The analysis of the tunic in 2013 suggested that it originally had been sleeveless and that the sleeves were a later addition. Should the reconstruction then be a sleeveless tunic or should it be the tunic worn with the sleeves half torn off? The tunic was made with long, untorn sleeves and without patches on the back (fig. 12). The cutting and sewing was done by professional tailors at Heimen Husflid in Oslo. They used the thread made at Selbu Spinneri. This was the same thread as was used for the weaving of the cloth. This sewing thread was not easy to work with, as it was too hairy for this purpose. Therefore, the tailors used beeswax to smoothe it before sewing by hand. They used the same stitches as in the original tunic. It took them approximately eight hours to cut and sew together one tunic.

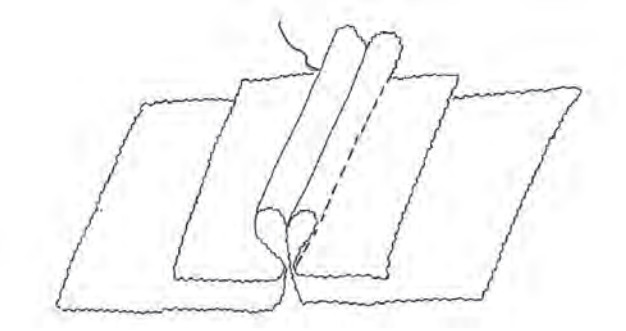

Fig. 11. The Thorsberger seam was used to join the body part on the left side of the tunic (After Möller Wiering 2011).

Conclusion

There are many steps in the production chain of a garment: from harvesting the wool through spinning, weaving, cutting to sewing. As demonstrated in the Lendbreen reconstruction project, it was a very time-consuming process. The wool used in the original yarn contains a mix of finer and coarser fibres and some very coarse fibres, possibly kemp, but the length of the fibres or how the original fleeces were composed before sorting is not known. This makes it hard to tell how much time was spent on sorting, fibre separation, teasing and combing before the actual spinning. The yarns in the original tunic have an even appearance, which could indicate that the wool was combed before spinning. A combed fibre material would reduce the

Wool collection and first sorting	2 hours
Second sorting and fibre separation	90 hours
Combing and spinning with spindles according to the experiment	540 hours, c. 14,625 m yarn
Weaving the two fabrics including finishing treatment	156.5 hours 5.5 sq m
Cutting and sewing	16 hours
Estimation of total work time for the two reconstructed tunics	804.5 hours

Table 1. The approximate time used to produce the two tunics.

Fig. 12. Cecilie Eskild at Heimen Husflid with the two finished tunics: one made for the Museum of Cultural History in Oslo, the other for the Norsk Fjellmuseum in Lom (Image: Marianne Vedeler, Museum of Cultural History, UiO).

spinning time compared to a teased material, if an even yarn is desired. The yarns in the Lendbreen tunic can be described as common, standard Iron Age yarns and would not have demanded any specialist knowledge to produce. Both fabrics in the tunic are woven in 2/2 diamond twill. This weaving technique requires specialist knowledge when woven on the warp-weighted loom. Compared to tabby and plain 2/2 twill, knowledge about pattern units and counting is needed for both the heddling and the weaving.

In Table 1, the time required to produce the two tunics in the reconstruction project is shown. From this, it is evident that wool preparation and spinning is more time-consuming than the weaving, finishing treatment and sewing.

In prehistory, the time spent on fibre preparation, spinning and weaving must have varied greatly depending on differences in the raw materials and the tools used, and the knowledge and skills of the people producing the textiles. It must still have been a very time-consuming task to produce a textile. This applies to everyday fabrics as well as to the most valuable ones. Archaeological finds have shown that textiles were often reused not only as re-tailored garments, but also for many other purposes. Excavations from medieval Tønsberg and Oslo in Norway have revealed textiles reused as tar brushes, as toilet paper or as material for sealing in houses and boats (Universitetsmuseenes gjenstandsdatabaser). Another way to get a realistic view of the value of prehistoric textiles could be to look at the relationship between production costs and circulation time. This could also be an interesting focus in the light of today's problems of textile overconsumption and growing amounts of textile waste.

One of the goals with the Lendbreen reconstruction project was to create two new tunics as similar as possible to the original. But there was also a broader aim: to gain greater knowledge of time and labour used in each step of the chain of production by analysing the original fabric. It is known that prehistoric textile production was a very time-consuming process, but timing each step of the process gave a more detailed picture. A striking example is the time-consuming process of sorting and separating fibres into different qualities. Some questions will never be answered because the original fabrics do not provide the required information.

There is still a need to look further into the direction of the warp and weft but it is now clear what to search for when the original tunic is available for new analyses. The narrow tablet-woven band is an area that needs further investigation, as are the some weft crossings. Those will be easier to find and recognise next time the Lendbreen tunic is examined. The light stripe consisting of four bright threads is puzzling. Is it an error or a decoration? This question leads to another: was the mottled fabric originally used for something else? This remains a matter of speculation.

The original tunic is in the collection of the Museum of Cultural History (UiO) in Oslo, and will be on display at the Norwegian Mountain Centre in Lom in Norway from 2018. One of the reconstructions can be seen at the same museum from 2017.

Acknowledgements

Ingvild Svorkmo Espelien and Selbu Spinneri in Klæbu in Norway did a great job spinning the yarns for the two reconstructions of the tunic from Lendbreen. Espelien also coordinated the spinning experiment that took place in 2015. Many thanks to Cecilie Eskild and her team at Heimen Husflid in Oslo for cutting

and sewing the two reconstructions. Thanks also to sheep farmer Alv Ottar Folkestad and his flock at Aursneset, Eiksund in Ulstein who provided the wool. The project was funded by the Museum of Cultural History at the University of Oslo and the Norwegian Mountain Museum in Lom. Many thanks!

Notes

1. The spinners were: Ingvild Svorkmo Espelien, Sissel Brun Ellevseth, Linda Thiis, Lillian Koehler, Henriette Aasen, Reidun Lien Horgen, Marianne Glørstad, Ingvild Sjøbakk. Spinning experience, weight and diameter of spindle were documented.

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Corresponding author:
marianne.vedeler@khm.uio.no