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Contents

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Projects

Obituary

Conferences

Editorial

Welcome to the world of textiles 2019. We hope that everybody across the many different textile communities of Europe and beyond have had a fruitful year with great events and huge successes!

The transformation of the *Archaeological Textiles Review* (ATR) into a mainly internet-based journal is almost complete. It is still possible to purchase a hard copy of the journal from the print-on-demand service at the University of Copenhagen's webshop. However, we see a declining demand for this service and it is a questionable how long it will be financially viable to continue it. But even if ATR is not available as a printed copy in the future, the editors have no plans to close the journal. There is definitely a need for a specialist journal in our field and in the wider academic community because we cannot be sure that all the articles published here would have found their way into other journals. As long as we maintain high standards for our work, ATR will survive. To that end, we would like to thank the many excellent and hard-working peer reviewers who have helped the authors improve their contributions this year.

This year's issue contains an interesting mix of articles from a range of time periods and geographical areas, as well as textile-related projects and experimental works, which we hope readers will appreciate. Altogether, there are eight articles and six project descriptions which very well illustrate the many aspects of textile research currently underway. It is truly inspirational to see how many excellent researchers working in this field are capable of creating new and innovative projects with exciting results. We know from our work at the Centre for Textile Research in Copenhagen that there are many more projects which are not reported here. We therefore encourage everybody to share their knowledge and experience about the many textile-related projects and conferences which take place each year with their colleagues through ATR. Check the back of this issue for instructions on submitting articles and project reports, which are welcome before **1 May 2020**. We encourage you to send them to us as soon as they are ready, so that we can spread the editing work over the year and have appropriate time for the peer review process.

For the coming ATRs we would like to put more focus on needle binding/nålebinding and fabric created by looping techniques in general. We see a need to propose appropriate terminology and protocols for recording it, and if anyone would like to contribute to this topic, please do contact the editors (our email addresses are at the back of the issue).

Please also remember to send us news of PhDs, publications and conferences at any time so that we can be continue to be a hub for the archaeological textile community. We also welcome ideas for contributions for forthcoming issues – send us your ideas and proposals so we can discuss how best to accommodate them. The deadline is 1 May each year.

The next annual general meeting (AGM) of the Friends of ATR will be held during NESAT XIV in Oulu in Finland in May 2020 - we hope to see you there. More information is on our homepage at www.atnfriends.com.

The Editors

Anne Drewsen

Spinning for the gods?

Preliminary observations on prehistoric textile production at Hierakonpolis, Egypt

Abstract
Around 3500 BC, an adult elephant was sacrificed and buried in the elite cemetery of Hierakonpolis in the very south of Egypt. The elephant was given a burial similar to humans including a linen shroud. This shroud is just one of an impressive number of textiles found at the site illustrating a range of uses. The textiles of the late prehistory in Egypt, the predynastic period, have not yet been thoroughly researched, and the linen of the elephant's shroud therefore presents a unique opportunity to consider the time used to produce it and the expertise of the spinners and weavers. The information from textile tools found at Hierakonpolis can now also be added to this story. The results of research into the elephant's shroud and the textile tools question our perception of prehistoric society in Egypt just before state formation, especially in relation to the organisation of textile production.

Keywords: Egyptian prehistory, animal burial, linen shroud, spindle whorl

Introduction
Textile production in Egypt is mainly known from the pharaonic period, either in the shape of models or wall paintings in tombs (Vogelsang-Eastwood 1995, 9) or in well-preserved textiles such as those from Tutankhamun's tomb (Vogelsang-Eastwood 1999). Excavators of the 1800s and early 1900s had some understanding of textile production and the related tools, especially English excavators who were familiar with textile production from industrialisation. Flinders Petrie recognised and correctly registered textile tools (Petrie 1917, 53). However, later archaeologists had less knowledge of the processes, which resulted in incorrect identification and registration of tools (Jones 2001, 13). The main material known is from the Pharaonic period, both the Middle Kingdom (2055-1650 BC) and the New Kingdom (c. 1550-1070 BC). Two sites from those periods, Lahun and Amarna, are well researched and the results have been published - for example, *Evidence for linen yarn preparation in Ancient Egypt* (Granger-Taylor 1998) and *The ancient textile industry at Amarna* (Kemp & Vogelsang-Eastwood 2001).

However, the predynastic period was almost 1,000 years before the Middle Kingdom, which questions whether comparisons can be made without interpretation being unduly influenced by the later processes. For Egyptian prehistory, textile research is mainly based on finds from burial sites, as few settlements have been excavated resulting in very limited access to information about domestic spaces with their associated tools and household textiles. Furthermore, the burial sites were often heavily robbed, meaning that any data from the burials should be treated with caution. Tomb robbers typically displace both grave goods and the body leaving bones and textiles from the burials to disintegrate on the surface making it difficult to judge to what extent textile was used in the burial. The elephant's tomb at Hierakonpolis (HK6 Tomb 24) was robbed, too, but due to its size, enough textile fragments remain to provide the basis for research (Friedman 2003, 9-10). Fortunately, textile is also found in numerous other sites, such as Badari and Mostagedda (Jones 2007, 982); the best known piece of textile is the Tarkhan tunic which has been 14C-dated to 3482-3102 BC, i.e. at the very end of the predynastic period (Barber 1991, 147, UCL 2016). The research is further limited by a lack of typologies and catalogues. Predynastic textile remains from nine sites have been compared (Jones 2008); the first analysis of early textile tools from Egypt undertaken (Spinazzi-Lucchesi 2018); and more work is currently underway, such as a PhD thesis by Alistair Dickey, University of Liverpool: *Textile of the elite and non-elite at ancient Nekhen* (Nekhen is the ancient Egyptian name for Hierakonpolis). This renewed interest in early Egyptian textile production will fill the gaps and make it possible to analyse the economic and ritual impact of textiles.

Textiles in early Egypt

From prehistory to the end of the Pharaonic period, Egyptian textiles are usually linen made from flax (*Linum usitatissimum*) woven in a tabby weave (Vogelsang-Eastwood 1992, 1). The process of turning flax into textile requires several steps, each of which necessitates a certain expertise (Vogelsang-Eastwood 1992, 1-35, Andersson Strand et al. 2010, 24-26). Flax may be described as easy to grow, but it has very specific requirements, such as slow running water, and must be harvested by pulling the roots, not cutting. The further extraction of fibres from the stems is no less time consuming (Andersson Strand et al. 2010, 24-26).

At the predynastic site of Hierakonpolis, an impressive quantity of textiles has been found, illustrating a range of uses. Textiles are found in burials in the workers' cemetery (HK43) and fragments are found in many of the robbed human burials in the elite cemetery (HK6) in addition to the burial of the elephant in Tomb 24 (Jones 2002, 13). Textile is also incorporated into the wooden walls of fences and structures in the elite cemetery, including the pillared halls, connected to ritual offerings, where the textile was plastered and painted in bright red, yellow, green and black (Friedman 2011, 187; Friedman, nd). Model objects, some possibly representing a shield and quiver, or a backpack found in a burial are also made from linen that has been plastered and painted (Droux 2016, 5; Hendrickx & Eyckerman 2017, 9). In the courtyard of a house within the settlement at HK11, a few bundles of yarn were found as well as spindle whorls and textile fragments, although in very modest amounts (Jones 2001, 13). The yarn at HK11 was analysed and found to be of good quality, finely and evenly spun with most of the fragments showing evidence of a new spinning technique which produced S-spun yarn (Jones 2001, 13). In general, the textiles found in the Naqada II phase of the Predynastic period show that the textile workers had acquired the expertise to produce linen of good quality that was evenly spun and woven (Jones 2002, 13-14). Furthermore, analysis of the Hierakonpolis textiles shows that textiles were produced in both fine and coarser qualities suggesting control, standardisation, and administration (Jones 2002, 13). The use of textile in burials was conventional – a single shroud wrapped around the body, and in a few examples of early mummification, pads of fine quality textile soaked in resin wrapped around wrists and neck, probably to maintain articulation in the afterlife, and a shroud for the entire body made from textile of a coarse quality. This use of textiles is also found at HK6 (Jones 2002, 13).

Just a few hundred years later, in the Early Dynastic period, evidence shows specialised workshops that are attached to religious or administrative institutions such as in Buto, where a stone vessel workshop was housed in a building connected with rituals and/or administration (Köhler 2010, 40). As early as 2900 BC, textiles are mentioned in historic records in the shape of the so-called "linen lists" which were a part of offering scenes detailing the amount and type of linen given to the deceased. In the royal tomb of the Late Predynastic period, tomb U-j from Abydos, small ivory labels are found and believed to have been attached to bunches of linen given to the king as grave goods (Jones 2010, 81, 83). Throughout the Pharaonic period, textiles were produced for gods and kings in specialised workshops. Those working for gods and kings received part of their wage in textiles.

The elephant's shroud

Hierakonpolis is a unique site for the prehistoric archaeology of Egypt, particularly the latter part of the prehistoric period also known as the predynastic period or the Naqada period (4000-3000 BC). It has been excavated since the late 1800s, and for more than the last 30 years, by the same team. It documents multiple aspects of an early society with settlement, ritual structures, production areas, and elite and workers' cemeteries. All this served a strong power centre with a population of possibly as many as 5,000 to 10,000 persons during the Naqada II period, c. 3500-3200 BC. Hierakonpolis is considered to be the most important city in the south of Egypt, providing evidence for the first kings and religious practices in the area (Friedman 2011, 44), and ultimately becoming one of two major cities vying for power at the time of the unification of Egypt under one king (Wengrow 2006, 73-74, 80). The elite cemetery, HK6, features fenced-in burial complexes and superstructures (including a pillared offering hall), not seen anywhere else in Egypt in this time period. Although animal burials are not abnormal, there are usually only few animals buried and not at every site (Flores 2004; Wengrow, 2006, 59). However, in HK6 animal burials are taken to a much larger and complex scale with more than 100 animals - from the cattle and dogs seen in other sites, to exotic beasts such as a leopard, several baboons, two crocodiles, two aurochs and two adult elephants. In the burial pits of the largest animals, such as the leopard, one of the aurochs, perhaps one of the crocodiles as well as the two elephants, textile remains have been found suggesting they were buried in shrouds (Friedman et al. 2017, 274-275). One of these shrouds, the shroud of the elephant in Tomb 24, is the case study for the calculation of textile production time. Textile from the predynastic period is often found in small fragments which makes it difficult to calculate size and thereby production time. Despite this particular burial having been robbed, parts of the body of the elephant were found in situ with the textile adhering to the body both on the top and on the bottom, as well as on the side of the pit. It is this distribution which strongly suggests that the textile was wrapped around the animal (Friedman 2003, 9-10). An analysis of the elephant's bones showed that it was 6 to 10 years old and stood 2 m to 2.5 m in shoulder height (Friedman 2004, 149). The textile distribution and its implications provide a unique opportunity to estimate the size of the shroud and consequently the production time for it (Jones 2002, 13; Drewsen forthcoming). The fragments of the shroud are in parts well-preserved (fig. 1), and described as follows:

"A fragment of textile from the side of the tomb was selected for examination under a stereomicroscope because it was extremely well-preserved, still pliable, and a beautiful creamy gold colour ... The yarns are mostly single, s-spun, with a few s2S plied yarns. Thread diameters are fine to medium, ranging from 0.18 mm to 0.3 mm. The warp yarns are more tightly spun than the weft, which were laid at an angle of 60 degrees to the warp ... The weave is of medium density, with a thread count of 20 x 10 yarns/cm, a ratio of 2:1.This ratio is traditionally associated with textiles of a later date, as most Predynastic textiles have a ratio of 1:1, including those from the burials at HK43." (Oldfield & Jones 2003, 12).

Fig. 1: Micrograph of a well-preserved fragment of the textile from Tomb 24 (14x magnification) (after Friedman 2003, 8-9; image: R. Oldfield)

Using tests carried out at the Ribe Viking Center in spinning and weaving flax, the production time can be calculated, though it should be noted that the tests were not carried out with replicas of Egyptian material and that they are therefore only an approximation. A piece of textile large enough to cover an adult elephant would be about 20 m^2. The thread count of 20:10 threads per cm is equal to a total of 60,000 m of spun yarn needed for the shroud. Since the tests have shown that an experienced spinner can spin an average of about 56 m of thread per hour (Ejstrud et al. 2011, 62), the final production time for spinning is 1,071 hours. This does not include harvesting the flax and processing it to the point at which spinners can use the fibres, which is a time-consuming process (Andersson Strand et al. 2010, 24-26). The tests also show that an experienced weaver can produce an average of 5 cm of fabric per hour (Ejstrud et al. 2011, 67). However, this is on a warp-weighted loom. So far, there is no evidence of vertical looms before the New Kingdom (Vogelsang-Eastwood 1991, 35) and the relevant loom would therefore most likely have been a ground loom or horizontal loom producing textiles with a maximum width of 100 cm to 130 cm (Vogelsang-Eastwood 1993, 6). The shroud would then have consisted of a minimum of four lengths, each of 5 m, to reach a total of 20 m^2. With a production rate of 5 cm per hour, the total time required for weaving the shroud is estimated at 400 hours. This does not include setting up the loom, which is another time-consuming process (Ejstrud et al. 2011, 62). The grand total is 1,471 hours. Divided by eight hours of work every day, it would have taken one person more than six months to produce this shroud. Since the shroud is only one of many pieces of textile, it underlines the fact that textile production is an extremely time-demanding process, which would have necessitated specialists working full-time at spinning and weaving. Due to the state of the fragments of the shroud, it is not possible to determine whether it is a piece of repurposed textile. However, in general, the textiles found in the workers' cemetery in Hierakonpolis, HK43, show no signs of repurposing, and it seems therefore that the textile was produced specifically for burial (Jones 2002, 13). Regardless, it was a wealthy society that allowed time-consuming production of textile purely for ritual consumption.

Tools

The use and need for the quantity of textiles for funerals is not in proportion with the amount of textile tools found in Hierakonpolis. Many have been excavated by Quibell and Green in the late 1800 (Adams 1974, 37, plate 26) in the Early Dynastic town at Hierakonpolis, amongst them limestone spindle whorls, such as the one at Liverpool Museum (inventory number 16.11.06.371a). Finds of pierced discs made from potsherds that could have been used as spindle whorls are also known from the Predynastic settlement sites, but except for a study of 12 ceramic disks found at HK11, the spindle whorls have not been intensively investigated (Jones 2008, 112). However, in 2016 a number of these pierced ceramic discs were studied by the author and are published in this article.

The pierced discs come from excavations at HK29, the house and workshop of a pottery excavated in 1978-1979 by Michael Hoffman (Hoffman 1982), and from HK29A, a predynastic ceremonial centre investigated in 1985-86, 2003 and 2008 by Michael Hoffmann and Renee Friedman (Friedman 2009). The discs from HK11 Square G, excavated in 2000-2001 by Ethan Watrall and previously studied by Jana Jones were also made available for study. The analysis was made as a preliminary study to inventory possible textile tools from the area, using a mobile phone camera for the photographic record and a small scale for recording weights. Subsequently professional photos were taken of the discs. In total, 39 discs were recorded from location HK29, 90 discs from location HK29A, and 19 from location square G, HK11 (tables 1-3 and fig. 2, see also description of the sites further below). The weights and dimensions of the pierced discs seem to suggest that the textile production at all three localities was not specialised for one type of textile but produced both yarn of fine or semi-fine quality and a few heavier, coarser qualities.

Clay spindle whorls are found in all sites not just the Naqada power centres. They are found in the settlement areas, for example at Adaïma (Midant-Reynes & Bucez 2002, 443-463). In El-Mahasna, pierced discs were also found in Block 3, which is interpreted as a ritual structure (Friedman, personal comment). In other cultures and periods, it is not uncommon to see tools in a burial but in the Predynastic period, Egyptian grave goods are primarily personal belongings such as ornaments and food for the afterlife, although pierced disks are known from some burials of the period at Hierakonpolis and elsewhere.

No.	HK Find No.	Diameter in mm	Width fragment/ hole-to-edge	Preliminary working description	Weight (actual)	Weight (if fragment, estimated)
141		28		Red on one side. Flat, roundish, edges uneven, some signs of smoothing. Hole attempted but not bored through. Missing about 1/5.	3.7	4.60
140		27		Red on one side. Flat, uneven, hole attempted, but not bored through.	4.8	4.80
144		30		Remains of red on one side. Flat, edges smooth. Fragment of 1/2	2.8	5.60
148		30		Red on one side. Flat, edges smooth. Hole attempted but not bored through.	6.1	6.10
130		30		Red on one side. Flat, smooth sides.	6.4	6.40
145		35		Red on one side. Flat, edges smooth. Fragment of 1/2	3.3	6.60
131		32		Red on one side. Flat, smooth side, a little tapered.	7.3	7.30
142		42	21	Black topped red ware? Flat, round, edges tapered and smoothed. Fragment of c. 1/4.	2.9	11.60
132		36		Red on one side. Flat, smooth sides. Fragment: 1/2.	6.4	12.80
137		44	22	Remains of red on one side. Flat, conical, edges smooth. Fragment ca 2/5.	5.4	13.50
139		48	24	Black on one side. Flat, conical form, smooth edges. Fragment of c. 1/2.	6.9	13.80
135		45		Remains of red on one side. Flat, conical, edges smooth. Fragment: 1/2.	7.2	14.40
143		52	26	Remains of red on one side. Flat, edges smooth and tapered. Fragment of c. 1/4.	3.6	14.40
133		44	22	Red on one side, very degraded. Flat, sides smooth? Fragment due to degradation - size about 3/4 of original.	11.5	15.30
138		42	21	Red on one side. Flat, smooth rounded edges. Fragment: c. 2/5.	6.7	16.80
134		46	23	Red on one side. Flat, sides smooth. Fragment c. 1/2.	10.7	21.40
146		68	34	Remains of black. Flat, edges smooth? Several bits broken off. Fragment of 1/4.	8.8	35.20
136		58	29	Black on one side. Flat, conic.l, edges smooth. Fragment c. 1/4.	9.0	36.00
129			62	Red on one side. Flat. Fragment, broken off along most edges. A hole attempted to be bored through on each side. Holes do not line up.	27.3	

Table 1: Preliminary list of discs found at HK11

No.	HK Find No.	Diameter in mm	Width fragment/ hole-to-edge	Preliminary working description	Weight (actual)	Weight (if fragment, estimated)
1	12	20		Black. Irregular, almost triangular, flat. Sides broken off? Hole not in the middle of the piece.	3.0	3.00
40		20		Red on both sides. Round, flat, hole on both sides, but not bored through.	4.2	4.20
11		24		Red on one side. Irregular, flat. Sides broken off? Hole not in the middle.	4.3	4.30
2	12	35		Red, polished on flat side. Round, sligthly convex.	7.0	7.00
159		36		Red on both sides. Round, edges smoothed and tapered to one side. Hole attempted, but not bored through. Hole not centered.	7.8	7.80
162		38	19	Red on one side. Round, edges smoothed. Fragment of c. 2/5.	3.1	7.80
161		35		Round, conical, smoothed. Fragment c. 1/2.	4.0	8.00
23		33		Roughware? Round.		8.40
3	12	34		Red on one side. Broken in half, flat.	5.2	10.40
160		44	22	Red on one side. Round, edges not smoothed. Fragment c. 2/5.	7.1	10.70
26		40		Red on one side. Round, taperede at the sides, flat.	10.8	10.80
27		52	26	Red on both sides. Fragment c. 2/5 of full shape. Round, taperede at sides.	5.8	11.60
29		60	30	Blacktopped redware. Fragment of c. 1/4 of full shape. Round tapered at the sides.	6.2	12.40
10			40	Red on one side. Broken, not quite in half, very similar to No. 2	6.2	12.50
30		34	17	Red on one side. Fragment, c. a quarter of full shape. Flat, tapered.	3.3	13.20
22		35		Red on one side, black on the other. Round flat shape, hole not bored through. Hole placed off-center. Scratches around hole.		13.50
31		42		Red on one side. Broken in c. half. Flat, tapered at sides.	7.0	14.10
32		40		Black on one side. Flat round, roughwarely tapered at sides.	14.2	14.20
25		41		Black. Round, broken in half, tapered at the sides.	7.9	15.80
28		45		Red on one side. Broken in c. half. Flat, tapered at sides.	7.9	16.00
39		49		Red. Irregular shape, flat, rounded from side.	20.5	20.50
5		50		Red on both sides. Broken in half. Round, sligthly convex - flat on both sides, but side slightly rounded one side (no top on this side).	10.5	21.00
24		49		Red on one side. Round, broken in half, tapered at the sides.	10.7	21.40
34		41		Red on one side. Flat round, broken in half, hole not bored through.	12.5	25.00
20		57		Red on both sides. Round, slightly rounded seen from the side, flat.		25.20
13		45		Dark red on both sides. Round, flat, broken in half.	13.4	26.80
35		56	28	Red on one side. Flat round tapered at sides, konvex, fragment of 1/4 of full shape.	6.7	26.80
158		60		Red on one side. Round, edges smoothed and tapered, fragments broken off.	28.2	28.60
12		54		Coarseware. Round, flat.	28.7	28.70
33		48		Red on one side. Flat round, broken, fragment of c. 2/3 of full shape.	19.9	29.90
19		57		Red on both sides. Round, part of side broken off, hole not bored through completely.	32.1	32.10
8		52		Red on one side. Broken in half, flat, clear curve seen from the side.	18.4	36.80
14		52	26	Round flat, slightly tapered sides, broken, c. 1/4.	9.9	39.60
17		68		Roughware. Round, 2 holes not bored through completely. Slightly rounded from side.	46.9	46.90
6		62		Roughware. Round, sides rounded towards one side, no top (not completely convex). Hole not bored all the way through.	44.6	89.20
4			52	Roughware. Broken, flat.	31.6	
9			58	Red on one side. Broken, clear curve seen from the side. Max width from hole to side: 49 mm.	15.0	
18			42	Roughware. Square fragment, remains of hole visible.	12.4	
7			58	Roughware? Broken, flat, hole not bored properly from both sides.	32.0	

Table 2: Preliminary list of discs found at HK29

No.	HK Find No.	Diameter in mm	Width fragment/ hole-to-edge	Preliminary working description	Weight (actual)	Weight (if fragment, estimated)
59	0447	20		Red on one side. Flat, smooth edges, not completely round. Hole attempted on one side, but not bored through.	2.6	2.60
63	0409	24		Roughware. Flat, irregular shape.	3.4	3.40
94	0516	25		Red on one side. Round, conical, smoothed. Fragment of 1/2.	1.9	3.80
83	0492	32	16	Round, edges smoothed and tapered, fragment of 1/3 size.	1.4	4.20
50	0437	32	16	Flat, round, smooth edges. Fragment 1/3 of full size.	1.5	4.50
51	0438	28		Flat, tapered rough edges. Hole attempted, but not bored through.	4.8	4.80
93	0517	28	14	Red on one side. Round, conical, smoothed. Fragment of 1/4.	1.2	4.80
77	0422	27		Red on one side. Round, irregular shape, holes on each side but not bored through. Holes do not completely line up. Edges somewhat smoothed.		5.90
91	0520	34	17	Red on one side. Round smoothed tapered edges. Fragment of c. 2/5	2.5	6.30
76	0421	28		Irregular shape, hole not centered. Wearmarks of hanging? Edges not smoothed.		6.70
98	0511	32	16	Red on one side. Round, smooth edges. Fragment of 2/5.	2.9	7.30
116	0484	42	21	Red on one side. Flat, smooth edges. Fragment c. 1/4.	2.4	7.60
52	0439	32	16	Flat, edges tapered to convex. Fragment 1/3 of size.	2.6	7.80
106	0500	31		Red on one side. Round, smooth edges. Fragment of ½.	3.9	7.80
79	0424	28	14	Red on one side. Round, flat, smoothed edges. Fragment of 1/4 size.	2.0	8.00
107	0498	32		Red on one side. Round, smooth edges. Fragment of ½.	4.0	8.00
113	0493	30		Flat, smooth edges, convex. Fragment: 1/2.	4.1	8.20
42	0430	31		Red on both sides. Flat round, fragment about half size, hole not bored through.	4.1	8.20
47	0434	80	40	Black/red on one side. Flat round uneven backside, slightly tapered. Fragment of 1/2 full size.	4.2	8.40
112	0491	36	18	Flat, tapered from both sides, smooth edges. Fragment: 1/5.	1.7	8.50
119	0486	38		Red on one side. Flat, smooth edges that are tapered from both sides. Fragment: 1/2.	4.6	9.20
90	0522	48	24	Black on one side. Round, thin, tapered smoothed edges. Fragment of c. 1/3.	3.1	9.30
69	0413	31		Red on both sides. Round, flat, edges not smoothed. Wearmarks consistent with hanging.		9.30
103	0503	34	17	Black on one side. Round, smoothed edges. Fragment of c. 1/5.	1.9	9.50
126	0476	34	34	Red on one side. Flat, round edges, smooth edges. Fragment: Little less than 1/2.	4.6	9.60
53	0440	34		Roughware. Flat, rough. 2 holes attempted, but not bored through.	9.7	9.70
57	0449	37		Red on one side. Flat, partly smoothed edges. One hole drilled right through, one hole attempted. Ring edged around the holes.	9.8	9.80
85	0530	33		Roughware. Round, flat, not smoothed. Fragment of c. 1/2.	4.9	9.80
72	0416	38	19	Round, flat, smoothed edges. Fragment of 1/4 size.	2.5	10.00
95	0513	36	18	Black on one side. Round, smoothed edges, fragment of 2/5.	4.0	10.00
104	0502	38	19	Light colour on one side. Round, smooth edges. Fragment c. 1/5.	2.0	10.00
102	0504	40		Roughware. Round, rough edges.	10.1	10.10
124	0478	35		Roughware? Flat, edges rough. Hole attempted, but not bored through.	10.3	10.30
44	0429	40		Black glitted. Flat round (edges not tapered).		10.70
121	0481	36	18	Red on one side. Flat, smooth edges, tapered from both sides. Fragment: c. 1/4.	2.8	11.20
66	0408	37		Flat, smoothed edges.	11.6	11.60
68	0414	39		Roughware. Square, flat, edges not smoothed.		11.80
49	0436	32	16	Red on one side. Convex, smooth edges. Fragment 1/4 of full size.	3.0	12.00
64	0427	40		Blacktopped redware. Flat, smoothed edges. Fragment of c. 2/3 of full size.	8.1	12.20
115	0489	48	24	Red on one side. Flat, convex, smooth edges. Fragment c. 1/4.	4.1	12.40
92	0518	38	19	Red on one side. Round, smoothed edge, tapered. Fragment of 1/4.	4.1	12.40
71	0417	48	37/24	Round, convex, smoothed. Fragment of a little less than half.	6.1	12.50
80	0425	44		Red on one side. Round, flat, slightly conical, smoothed. Fragment 1/2 size.	6.8	13.60

Table 3: Preliminary list of discs found at HK29A

120	0485	38	19	Red on one side. Flat, smooth edges. Fragment c. 1/4.	3.4	13.60
58	0450	40		Roughware. Flat, not smoothed. Attempt at boring holes at both sides, but none going through.	13.7	13.70
46	0432	43		Red on one side. Flat round, edges smoothed but not tapered. Fragment 1/2 size.	6.9	13.80
110	0495	37		Roughware. Flat round, edges somewhat smoothed, hole not bored through.		13.80
74	0419	40		Roughware. Round, edges smoothed, fragment of 1/2 size.	7.0	14.00
87	0525	46	23	Roughware. Round, smoothed edge. Fragment of c. 2/5.	5.6	14.00
122	0480	40	20	Black. Flat, edges smooth and tapered. Fragment c. 1/4.	3.6	14.40
97	0510	42	42	Round, smoothed edges. Tapered from both sides. Fragment of 1/2.	7.4	14.80
73	0418	44		Round, flat, edges smoothed. Fragment of c. 1/2 size of full size.	7.5	15.00
99	0507	44	22	Red on one side. Round, smooth edges. Fragment of 1/3.	5.0	15.00
105	0501	39		Round, smooth edges, tapered from both sides. Fragment of 1/2.	7.7	15.40
114	0490	46	23	Red on one side. Flat, convex, smooth edges. Fragment c. 1/5.	3.1	15.50
78	0423	40		Roughware. Round, slightly conical form, smoothing of edges. Fragment of c. 1/2.	7.9	15.80
61	0451	38		Roughware. Flat, edges smoothed.	15.8	15.80
88	0524	42		Red on one side. Round, conical, smoothed. Fragment of c. 1/2.	8.0	16.00
123	0479	42		Flat, edges smooth and tapered. Fragment c. 1/2.	8.4	16.80
62	0410	36		Red on one side. Flat, edges smoothed, fragment of c. 1/2 of full size.	8.4	16.80
125	0477	36	18	Red on one side. Flat, conical, edges smooth. Fragment: 1/3.	5.9	17.70
89	0523	46	23	Red on one side. Round, tapered, smoothed edges. Fragment of c. 2/5.	7.1	17.80
111	0494	48		Flat round, edges smooth, tapered from both sides. 2 fragments glued making up 1/2 of a full whorl.	9.2	18.40
82	0531	66	33	Round, flat. Edges little smoothed. Fragment of c. 1/4.	6.2	18.40
48	0435	54	27	Roughware? Flat, round, smooth edges. Fragment 1/3 of full size.	6.2	18.40
96	0512	52	26	Red on one side. Round, smooth, tapered edges. Fragment of 1/4.	6.1	18.40
54	0441	52	26	Red on one side. Flat, edges partly smoothed. Fragment c. 1/2 of size.	9.2	18.50
86	0527	49		Round, flat, edges smoothed. Fragment of c. 1/2.	9.8	19.60
128	0468	52		Red on one side. Flat, smooth rounded edges. Fragment: c. 3/5.	12.4	20.70
43	0428	48		Grey. Flat round, fragment about half size. Smooth.	10.4	20.80
75	0420	48	24	Red on one side. Round, flat, polished, tapered edges. Fragment of c. 1/3.	7.3	21.90
41	0431	50	25	Red on one side. Flat round tapered at sides, fragment about 1/3 of size of full shape.	7.3	21.90
118	0487	54	27	Red on one side. Flat, smooth edges, convex. Fragment: 1/4.	5.8	23.20
117	0483	36	28	Flat, convex, smooth edges. Fragment c. 1/4.	5.9	23.60
45	0433	49		Roughware. Flat round, two holes attempted but does not line up. No hole through.		26.00
127	0475	60	30	Black? Flat, tapered edges, smooth edges. Fragment: 1/3.	9.6	28.80
67	0412	49	49	Roughware. Flat, smoothed edges. Fragment of c. 1/2 of full size.	15.8	31.60
81	0535	42	21	Roughware. Round, flat, edges not smoothed. Fragment of 1/3.	11.4	34.20
56	0443	60	56	Roughware. Flat, rough edges. Fragment of a little less than 1/2 of full size.	17.8	37.00
100	0506	66	33	Round, smooth edges. Fragment of c. 1/4.	12.1	48.40
109	0496	68	34	Red on one side. Flat, round, smooth tapered edges. Fragment c. 1/4.	15.3	51.20
60	0448	69		Roughware. Flat, edges smoothed, smaller bits broken off.	66.2	66.20
84	0533	88	44	Roughware. Round, slightly conical form, smoothing of edges. Fragment of c. 1/4.	18.1	72.40
70	0415	79		Red on one side. Round, flat, edges smoothed. Fragment of ca 1/2 size of full size. Wobbly, cannot lie completely flat.	36.5	73.00
163	0385	32		Coarseware. Round, uneven edges, non smoothed.		
164	0386		32	Fineware. Round, uneven in size. Original size not possible to see.		
65	0411		30	Red on one side. Flat, irregular shape. Fragment, original size cannot be gauged.	5.1	
108	0497	44	22	Red on one side. Irregular shape, flat, tapered sides, bits broken of side. Fragment, size cannot be determined.	5.6	
55	0442		45/27	Roughware. Flat, rough edges. Broken on all sides, original size cannot be gauged.	12.6	
101	0505	56	28	Roughware, red on one side. Fragment missing part of two sides. Edges rough.	15.5	

Table 3 continued: Preliminary list of discs found at HK29A

Identification

All of the discs were repurposed potsherds, either pierced or showing signs of an attempt at boring a hole. The discs have been recorded on the premise that some may be the result of trial and error in making new spindle whorls and some of the fragmented objects may have been dropped too many times to be of further use for this purpose. This approach has some inherent problems; while it is not possible to classify all pierced discs as spindle whorls, it is equally difficult to exclude some when no typology exists (Jones 2008, 112).

In published catalogues, potential spindle whorls made from potsherds are sometimes rejected as being so. For example, in the catalogue from Brooklyn Museum, the pierced discs from Adaima were deemed "too light" in comparison to the more aesthetically pleasing decorated limestone spindle whorls (Needler 1984, 293-294, see also discussion in Midant-Reynes & Bucez 2002, 446-447). However, as the importance of the spindle whorls lies in their weight, one type cannot replace the other and it is more likely that both types were in use at the same time. Specifically for the Hierakonpolis material, there is an added question mark as the desert settlement at Hierakonpolis, from which most of the discs in this study were found was abandoned during the late Naqada II period when the settlement shifted closer to the Nile (Wengrow 2006, 92). It would be natural for the crafts people to keep the best tools and leave the broken behind and thereby also leave an uneven record of the tools actually used at that particular site. This could distort an understanding of the production process.

A question also arises regarding the use of the pierced discs. In the archaeological records, they have been registered using the neutral terms "pierced disc" or "pierced potsherd" or interpreted as "tokens", or "fishing net weights". The interpretation as tokens is usually relevant for any potsherd that has been worked into a disc whether pierced or not. It is not obvious for what the tokens would have been used. The idea of using the pierced discs as fishing net weights is relevant only in consideration of their weight. Most pierced discs are too heavy to float and too light to draw the fishing net down quickly. It is equally important to note that the objects may be multipurpose tools, or that a spindle whorl once too fragmented for that purpose, could have been used as a bottle stopper. Bottle stoppers are known from later periods, when the potsherd was wrapped with vegetable matter (plant stalks) to provide a secure stopper.

Material

The material of the discs has not been analysed in detail, but in general they are made from either coarse ware or fine ware such as blacktopped redware. While the coarse ware is tempered with straw and quite coarse in fabric, the fine ware with its denser fabric would have easier to polish on the edges and thereby giving less trouble with snagging the thin flax fibres.

Context

The majority of the pottery discs, 90 in total, are found in HK29A, the ritual structure in use during Naqada II. HK29A includes an unusually large, oval structure of 45 m x 13 m, with a number of refuse pits just outside the enclosure walls containing primarily animal bones of cattle and Nile perch as well as the largest collection of bones from wild animals from any predynastic settlement, all of which is connected with rituals (Friedman 2009, 81). The structure is a part of a ritual precinct covering perhaps one hectare with a fenced-in area encompassing the ritual structure itself and production areas for luxury items such as stone vessels, flint tools and beads. The production areas are described as workshops, although structural remains are not obvious, but evidence from them consists of considerable remains showing exceptional specialisation, including tools such as drills for stone vessel and bead manufacture as well as fine lithics

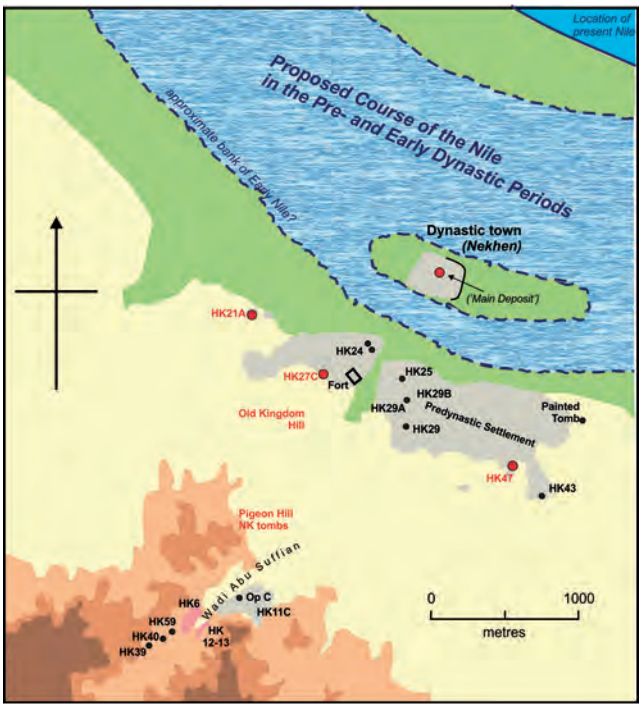

Fig. 2: Map of Hierakonpolis in the Naqada period (Image: P. Robinson)

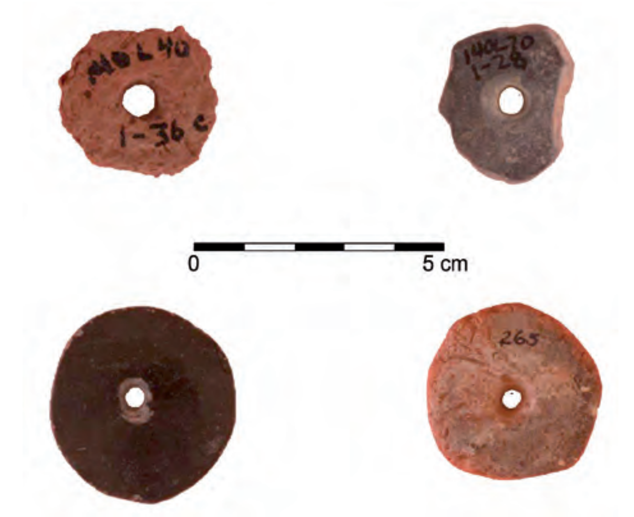

Fig. 3: Examples of pierced discs from HK29A (from top left: 163, 164, 44, 61) (Image courtesy of the Hierakonpolis Expedition)

(Friedman 2009, 85, 89, 98; Hikade 2011, 83, 105). In this area, the discs are tools of textile production, not the finished products themselves. Of the 90 discs, only 12 are intact, the rest are fragments. As the discs are made of potsherds, they will not tolerate being dropped on a hard or semi-hard floor without the edges breaking or snapping across the diameter and consequently losing their value as tools. The discs most likely relates to the specialised workshops attached to the ritual structure (Friedman 2009, 89). The weight of the discs found here range between 3.4 g and 37 g with four discs being much heavier at 48.4 g, 73 g, 66.2 g and 72.4 g (table 3 and fig. 3). In the neighbouring district to the southeast, HK29, 39 pierced discs were found of which only 12 are relatively intact (fig. 1). The weight ranges between 3 g and 39.6 g (fig. 4). HK29 is an industrial quarter bordering HK29A, the ritual structure, and amongst other feature a potter's house, preserved due to a fire. The remains from the pottery production suggest that the potter produced rough ware, not fine ware (Hoffman 1980, 129).

A total of 18 pierced discs were found at HK11 (square G), in the courtyard of a house (not fully excavated) in a settlement area in a wadi, 4 km from the Nile and 1.5 km from the edge of cultivation. HK11 is an enigmatic locality; being both the best preserved settlement area and the one which raises most questions regarding its location, as it lies so far from the Nile. HK11 is a site of c. 68,000 m^2 and includes a domestic area with houses to the northeast and breweries and food preparation on an industrial scale to the southwest (Friedman and Baba 2016, 179). HK11 lies in the same wadi as the elite cemetery, HK6 (fig. 2). Most of the discs were very fragmented, probably by being dropped during the spinning process that they cannot be used for spinning any longer (table 1 and fig. 5). Besides the discs, spun yarn and a piece of woven linen were found in a refuse pit. The proximity to HK6 raises questions of whether all or part of this site was established to service HK6

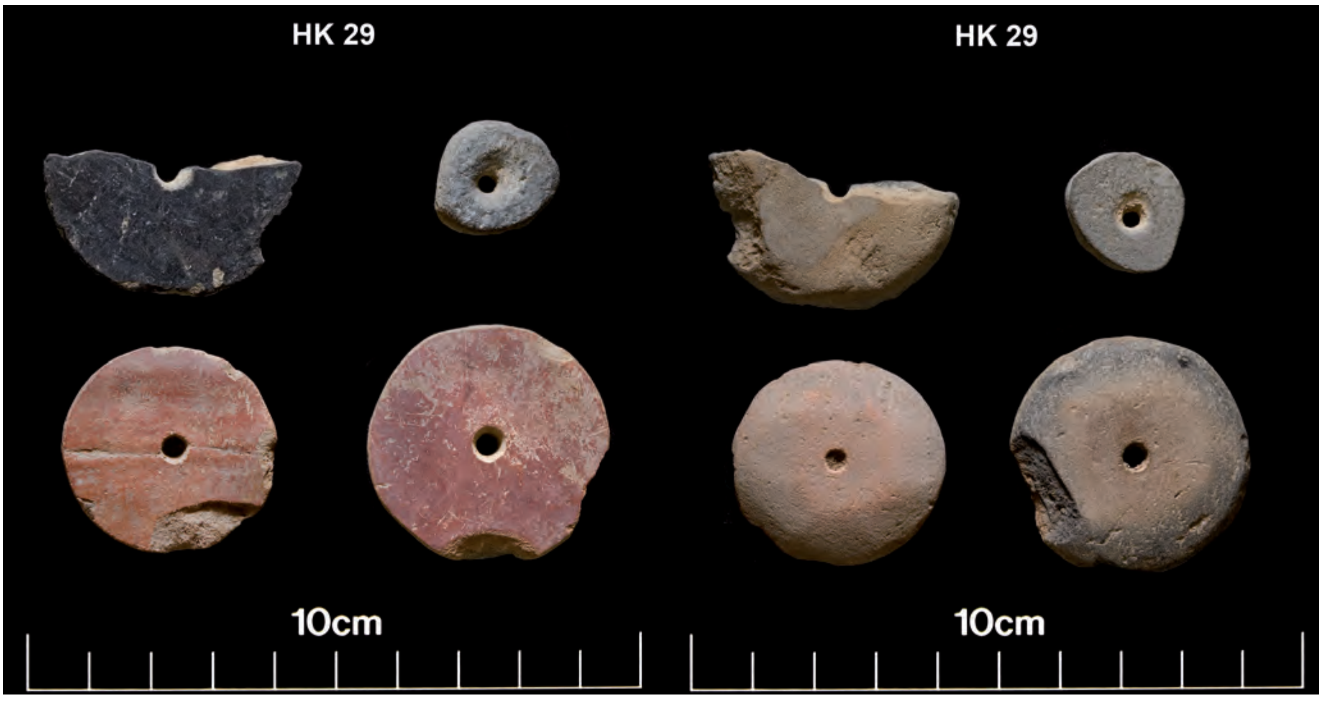

Fig. 4: Examples from HK29 (front and backside, from top left to right: No. 25, 1, 2 and 26) (Image courtsey of the Hierakopolis Expedition)

(Baba & Friedman 2016, 181) or perhaps to evade the annual flooding by the Nile (Watrall 2001, 8-9). The impressive amount of beer that can be produced at one of the breweries (Operation B) suggests it could easily supply the funerary cults at HK6 (Baba & Friedman 2016, 193).

Spinning for the gods?

Relatively little is known about rituals and religion, which gods were worshipped and how, in the Predynastic period. The fact that a number of pierced discs interpreted as spindle whorls have been found in relation to ritual structures is interesting. The finds of textile in all burials in HK43, as well as in many burials in HK6, point to textiles being used for ritual purposes in protecting the body. The use of textiles as padding for wrists and neck points to the aim of maintaining body articulation. The elephants and other powerful animals being buried in textiles could relate to preserving the power to protect the cemetery or perhaps limit their power in the afterlife. That textiles have been found in foundation deposits and used in walls in the pillared hall in the elite cemetery further suggest that textiles hold a ritual significance, perhaps as protection or as a separation between the sacred and profane. The find location of the pierced discs does not contradict this connection to rituals. The discs are found in connection with the ritual structure HK29A in an area connected with specialised workshops for fine objects. Likewise, they are found in HK29, an industrial area next to HK29A, where pottery was produced. They are also found at the enigmatic site, HK11, with evidence of food production beyond that of a normal household, and which lies close to the elite cemetery away from the Nile. On the other hand, pierced discs are rarely found in cemeteries such as the workers' cemetery, HK43. Jones sees the standardisation of textile quality not only as related to a specialised funerary industry, but also to an administration probably run by the elite. The textiles analysed proved to be of uniform quality, with evenly spun yarn, very few weaving faults and a surprisingly high thread count which points to an industry with specialised craftsmen and/or craftswomen. The technological change from a Z-spin to an S-spin at the start of Naqada II shows an understanding of the technologies contributing to a higher quality of finished product.

In combination, these facts suggest that at some time during Naqada II, the textile industry at Hierakonpolis was intentionally developed on a grander scale than household production with an impressive quantity of textiles produced and used for ritual purposes. Considering that a few hundred years later, textile workshops were part of both temples and court, producing textiles as payment for workers, for clothing the gods, and for other ritual purposes, this evidence suggests a new perspective on predynastic textile production, administration and organisation. It raises the question of whether the people of Hierakonpolis were already spinning for the gods in the Naqada period.

Fig. 5: Examples of discs from HK11 not to scale, see sizes in fig. 2 (Images: Anne Drewsen)

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Textiles from Zawaydah, Naqada, Upper Egypt

Abstract
The article presents the results of textile and fibre analysis of four textile fragments recovered during archaeological excavations at the site of Zawaydah, Naqada, in Upper Egypt. Although the main phase of the occupation at this site is ascribed to the Pre- and Protodynastic period (c. fourth millennium BC), the structural and fibre analyses of the textiles and the subsequent radiocarbon dating of two fragments provide evidence of later phases of site use, to be assigned to the Middle Kingdom, possibly the New Kingdom, and the Middle Ages (second millennium BC and second millennium AD). The article offers an insight into the Egyptian textiles of these latter time periods at the site, and highlights the importance of detailed structural and fibre analysis for acquiring dating information and informing the decisions to carry out further analyses, such as radiocarbon dating.

Keywords: Egypt, Zawaydah, Naqada, archaeological textiles, radiocarbon dating

Introduction

Five textile fragments were found during excavations conducted at the site of Zawaydah, Naqada, in Upper Egypt (fig. 1a), by the Italian Archaeological Mission of the then Istituto Universitario Orientale (IUO), today the University of Naples L'Orientale, Naples (Italy). These investigations took place from 1977 to 1986 under the direction of C. Barocas, R. Fattovich and M. Tosi (Fattovich et al. 2007). Zawaydah refers to a settlement site lying on a gravel terrace at the edge of the low desert, whose northern portion corresponds to the settlement known as South Town, investigated by W. M. Flinders Petrie from 1894 to 1895 (fig. 1b; Petrie & Quibell 1896, 50, 54, pl. IA, LXXXV). Naqada, the wider multi-component site where Zawaydah is located, is best known for its extensive cemeteries dated to the Predynastic period (circa fourth millennium BC), discovered and excavated by Petrie at the end of the 19th century (Petrie & Quibell 1896).

In the preparation of the finds and materials from the Italian investigations at Naqada for its final publication (Di Pietro, forthcoming), four of the five textile fragments retrieved during this fieldwork underwent in-depth analyses, the results of which are presented in this paper. Due to the problematic nature of the contexts from which these textiles were collected at Zawaydah, one of the main objectives of these analyses was dating them and defining their relationship with other material culture from the site. The latter, which also includes a conspicuous number of textile tools (Gleba & Di Pietro forthcoming) is to be associated primarily with the Pre/Protodynastic settlement at the site (Di Pietro 2017). The detailed structural and fibre analyses recently performed proved useful in providing crucial new dating information and informed the decision to carry out further analyses. An insight into the textiles of the Middle Kingdom, possibly New Kingdom, and Medieval Egypt, representing previously unknown aspects of the material culture of Zawaydah, can now also be offered as a contribution to ancient textile studies.

Material and context

The textiles examined in this paper were recovered from different squares and levels within two main trenches investigated at Zawaydah by the IUO Mission: ZWW (or Zawaydah west), excavated in 1979, and ZWE (or Zawaydah east), excavated between 1979

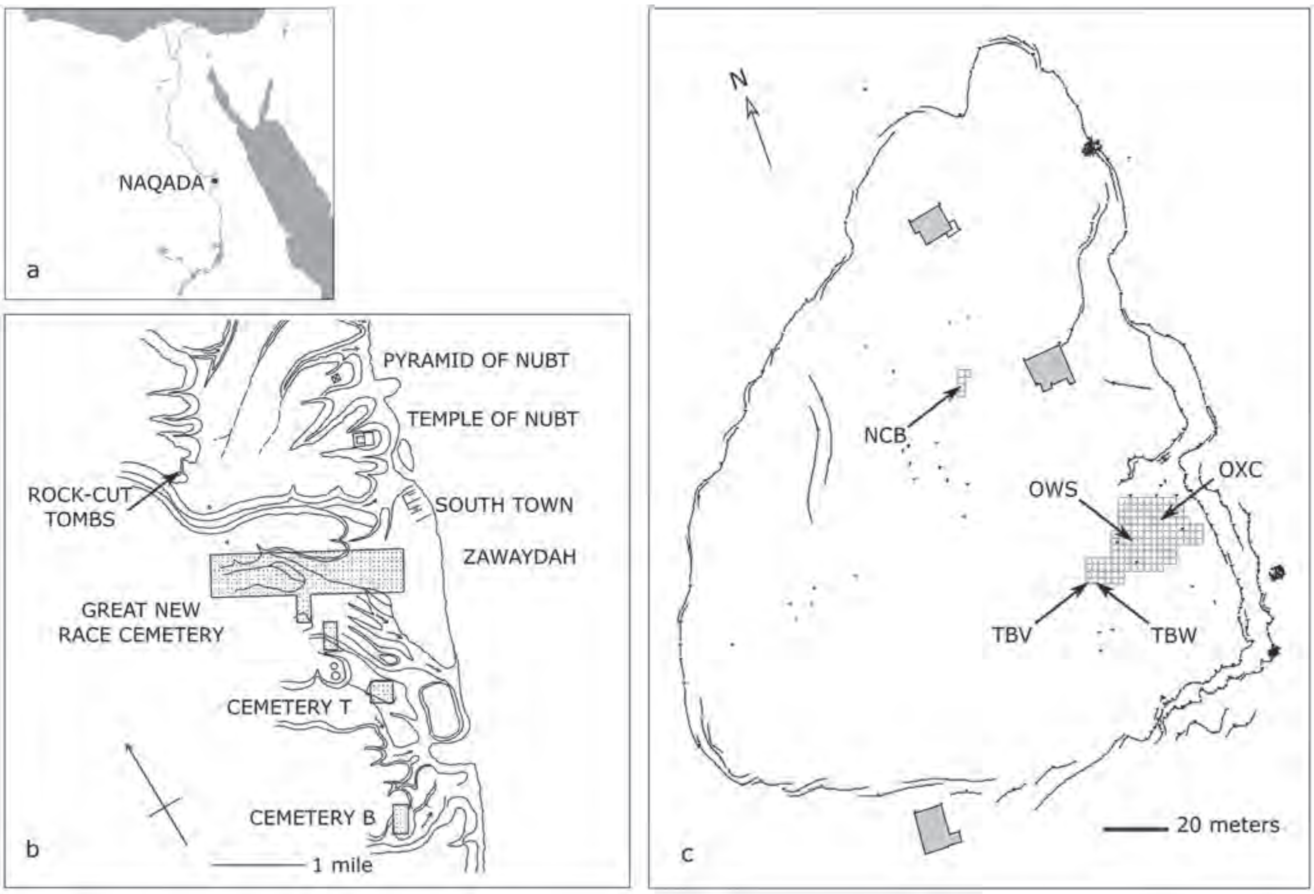

Fig. 1: a) Map of Egypt; b) Sketch map of the site of Naqada with an indication of the main sites explored by Petrie. The burial areas are stippled (after Petrie and Quibell 1896, pl. IA); c) plan of the site of Zawaydah with an indication of the squares where the textile fragments were collected (Image: Grazia Di Pietro)

and 1986 (fig. 1c). As far as the collection methods are concerned, based on the available archival records, it is unclear whether the textile fragments were hand picked over the course of the excavation or were collected from sieved deposits.

Four of the five textiles were exported to Italy, together with samples of other archaeological materials, in order to undergo analyses that could not be conducted in Egypt. This followed practices that were common and legal at the time of the fieldwork (in contrast to later constraints upon the transfer of archaeological samples out of Egypt) and are reflected in the documents on file in the archives of the IUO Mission. In recent years, these fragments, previously kept at the Bioarchaeological Research Centre of the International Association of Mediterranean and Oriental Studies (IsMEO) in Rome, have been made available for study, in anticipation of the final comprehensive publication of the finds from the Italian investigations at Naqada (Di Pietro, forthcoming). The fifth textile fragment, currently kept at the Storehouse of the Supreme Council of Egyptian Antiquities in Qift, was photographed during the 2008 and 2009 study season conducted by one of the authors in Egypt but could not be re-examined for the purpose of the present study.

Details regarding the context of recovery of all the textile fragments from Zawaydah and associated cultural material are presented in table 1, while a brief overview of the site's state of preservation and chronological framework is presented below. At the time of the Italian fieldwork, the site of Zawaydah had suffered ubiquitous disturbance. Although during the excavation different stratigraphic layers were distinguished, the deposits were too heavily disturbed to allow a clear subdivision of these vertical units in chronological terms.

Due to the dearth of samples deemed suitable for radiocarbon dating, pottery has been the key tool used for defining the chronology for the different cultural phenomena recorded at the site. In particular, the ceramic evidence indicates that the occupation in the area of the western trench (ZWW) covered a relatively

Field Inventory No	Context ID	Find Context
598 * * Textile fragment currently stored in Egypt.	TBV	Eastern trench (ZWE), Square 2x2m TBV; Context type: mixed deposit; Cultural material: textile fragment; pottery; lithics; fragments of miniature vessels; fragments of miniature boats; wooden fragment; bone and shell fragments.
676	OXC-hole 1	Eastern trench (ZWE), Square 2x2m OXC, posthole 1; Context type: backfill of voided hole (possibly post-hole, c. 22 cm deep); Cultural material: textile fragment; charcoal.
741	TBW-1	Eastern trench (ZWE), Square 2x2m TBW, Level 1; Context type: mixed deposit; Context description: the layer's matrix included abundant lumps of reddish and grey clay; Cultural material: textile fragment; a few pottery sherds; disk-shaped clay sealing with seal impression (possibly Naqada III); clay bead.
852	OWS-1	Eastern trench (ZWE), Square 2x2n OWS, Level 1; Context type: mixed deposit; Context description: layer with disturbed incoherent deposit; Cultural material: textile fragment; a few pottery sherds; clay bead; shell.
853	NCB-2	Western trench (ZWW), Square 2x2m NCB, Level 2; Context type: mixed deposit; Context description: textile fragment; layer of 'red soil' with sparse mudbrick and clay remains; Cultural material: textile fragment; pottery; lithics; a clay sealing with seal impression; beads; refined clay lumps; faunal and botanical remains.

Table 1: List and contexts of recovery of textile fragments at Zawaydah

broad stage of the Predynastic period: approximately Naqada I-II (circa 3700 BC to 3400 BC). A negligent component (ranging from 0.55 % to 2.96 %) of the ceramic assemblage may be connected to later (post-prehistoric) activity in this part of the site. This is confirmed by at least one clay sealing with an impression featuring a hieroglyphic inscription, found in the square IWV (level 1-2). In the area of the eastern trench (ZWE), the majority of the pottery can be assigned to the Late Predynastic-Protodynastic period (circa Naqada IIC-IID to Naqada IIIA; circa 3500 BC to 3150 BC; Di Pietro 2016). Here, too, a minor component of the ceramic assemblage (ranging between 10 % and 30 %) relates to a later occupational phase, or at least the site's use, dated provisionally to the New Kingdom (circa second half of the second millennium BC).

Based on currently available evidence, the major ancient phase of occupation at Zawaydah is to be ascribed to the Pre/Protodynastic period, with a minor phase possibly occurring in the New Kingdom. Human presence and activity at the site certainly predate the fourth millennium BC, as demonstrated by a few Palaeolithic stone implements retrieved here (Giuseppina Mutri, pers. comm. 2018), and presumably never ceased between the fourth and the second millennium BC as well as afterwards. Indeed, the temple of Nubt located nearby, to the north of the terrace of Zawaydah (fig. 1b), was in use almost continuously at least from the middle of the third to the early first millennium BC (Petrie & Quibell 1896, 34, 60, 65–70). Post-Pharaonic remains in the wider site of Naqada are also reported by Petrie (for example, some New Kingdom rock-cut tombs being re-used by Coptic hermits, fig. 1b; Petrie and Quibell 1896, 34, 69, pl. I-IA), and highlighted by the recent archive- and field-based research (Stevenson & van Wetering, forthcoming). Ongoing studies of the rest of the archaeological materials collected at Zawaydah by the Italian expedition, as well as forthcoming publications arising from investigations carried out at the site by other teams (for example, Stevenson & van Weterin, forthcoming) are expected to elucidate further chronology and character of human activity at the site, especially during the historical phases, which are poorly known so far. In the meantime, the results from the analyses that were performed on the textile fragments and are reported below add invaluable new information to the reconstruction of the complex history of this site, along with their contribution to ancient Egyptian textile studies.

Textile analysis

The structural examination of four textile fragments was carried out at the McDonald Institute for Archaeological Research, University of Cambridge. Digital microphotographs were taken using a portable Dino-Lite digital microscope at different magnifications (x 20, x 50, x 230 magnifications). The data on the fifth fragment 598 was extrapolated from a photograph (fig. 4). The summary of the structural textile analysis is presented in table 2.

One object (676) is a short cord fragment, while the remaining three fragments are woven in tabby (fig. 2). None of the fragments preserve any other structural features. The absence of edges precludes definitive identification of warp and weft direction.

The four objects analysed have different yarn structures (fig. 3). The cord 676 is Z-plied of two s-twisted yarns. Fragment 741 is woven in spliced and S2-plied yarn, with clearly visible splices. The slightly denser system in this fragment is most likely the warp, as is common with spliced Egyptian textiles, which tend to be warp-dominant, i.e. with more warp than weft threads per cm. Textile 852 is woven in single s-twisted yarn. Finally, textile 853 is woven in single z- or clockwise-twisted yarn. The threads appear to be unevenly dyed in a dark (originally black?) colour.

Although it was not possible to examine the fifth textile found at Zawaydah, the photograph taken during the preliminary examination in Egypt shows that this fragment, too, is a tabby, with circa 6 to 8 threads per cm in both systems and s-twisted yarn (fig. 4).

Fibre identification

Fibre identification and analysis of the textiles from Zawaydah were carried out at the McDonald Institute for Archaeological Research, University of Cambridge using Hitachi TM3000 TableTop Scanning Electron Microscope (SEM) in order to determine the morphological characteristics of the fibre and to acquire more detailed surface information for fibre

Fig. 2: Micrographs of textile fragments from Zawaydah (Images: Margarita Gleba)

Object	Weave	System 1 count	System 2 count	System 1 twist	System 2 twist	System 1 diameter	System 2 diameter	System 1 angle	System 2 angle
598	tabby	6-8	4-6	s	s	c. 1	c. 1	medium-hard	medium-hard
676	cord	NA	NA	S2z	NA	2.1-2.5	NA	low	-
741	tabby	15	10	S2*z	S2*z	0.5-0.9	0.4-0.6	NA	NA
852	tabby	15	10	s	s	0.5-0.8	0.5-0.9	medium-hard	medium-hard
853	tabby	14	?	z	z	0.5	0.6-0.8	medium	low

Table 2: Technical textile data summary (thread counts are in threads per cm; diameters measured in mm; NA=not applicable)

identification. The following instrumental settings were used: analytical condition mode at 15.00 kV accelerating voltage, compositional imaging and working distance of 5 mm to 10 mm. The fibres were examined longitudinally and, where possible, in cross section for morphological features. The diameter of fibres was measured using the SEM utility tool. The measurements were carried out at x 400 magnification. The samples were not coated. The results are summarised in table 3.

Fibres were well preserved, allowing identification of the raw material in all four cases. Fragment 741 is made of flax (*Linum* sp.), as indicated by the characteristic dislocations or nodes, the fibre diameters (table 2) and

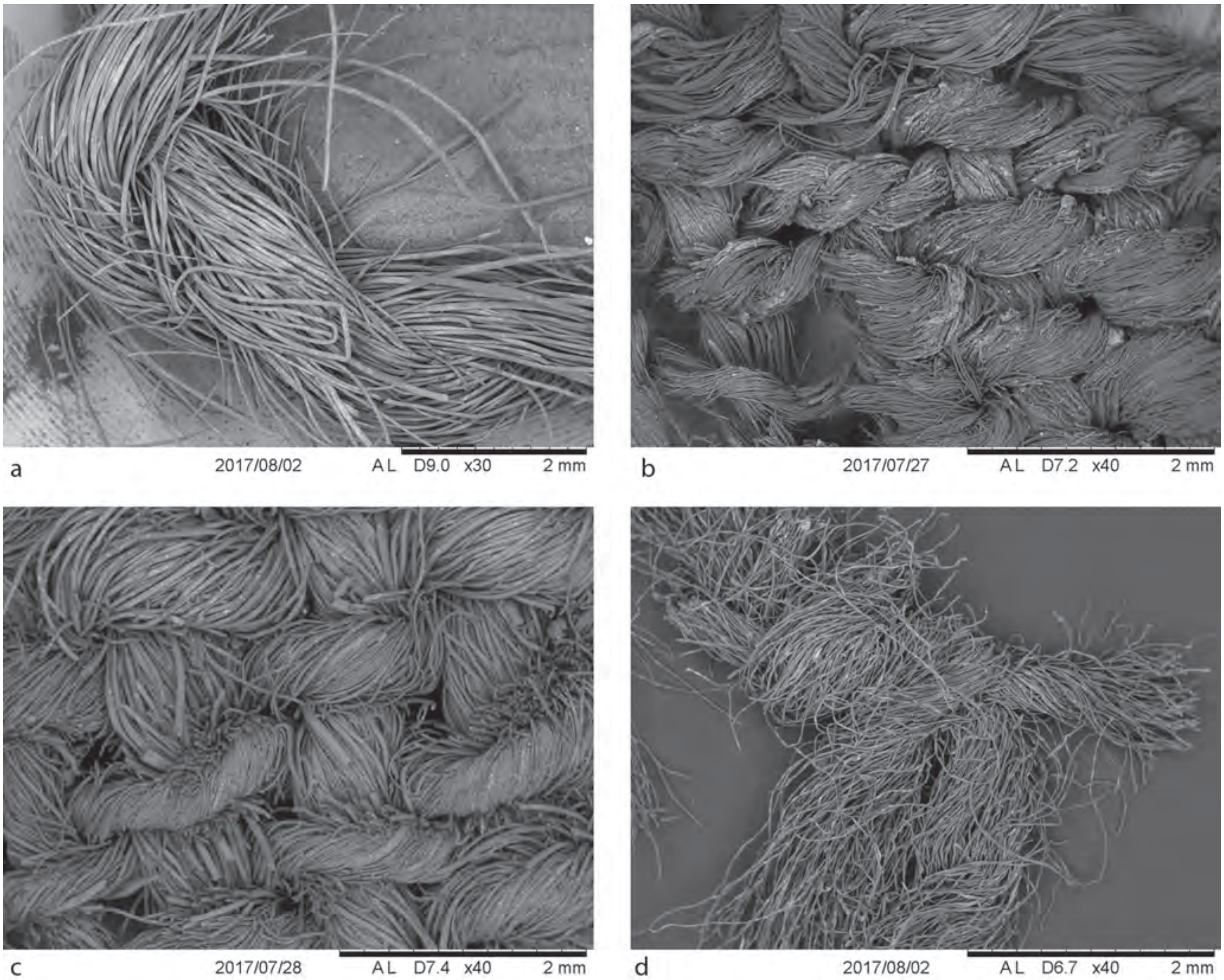

Fig. 3: SEMicrographs of textile fragments from Zawaydah: a) 676; b) 741; c) 852; d) 853 (Images: Margarita Gleba)

Object	Textile weave	No fibres	Mean	Range	Characteristics	Material
676	cord	67	42.4	19-69, 76, 84	irregular mosaic cuticle pattern	sheep wool
741	tabby	17	13.1	7.1-21.6	dislocations, bundles, splices	flax
852	tabby	136	27.3	11-113 with interruptions	irregular mosaic cuticle pattern	sheep wool
853	unidentifiable	15	19	15-21	ribbon-like flat structure	cotton

Table 3: Fibre identification data summary (mean and range are in microns)

Fig. 4: Image of the fragment 598 (Image: Grazia Di Pietro)

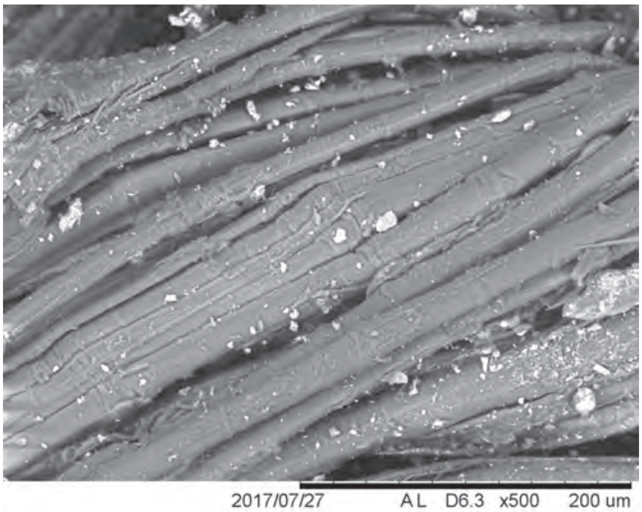

Fig. 5: SEMicrograph of fibres in Zawaydah textile fragment 741 (Image: Margarita Gleba)

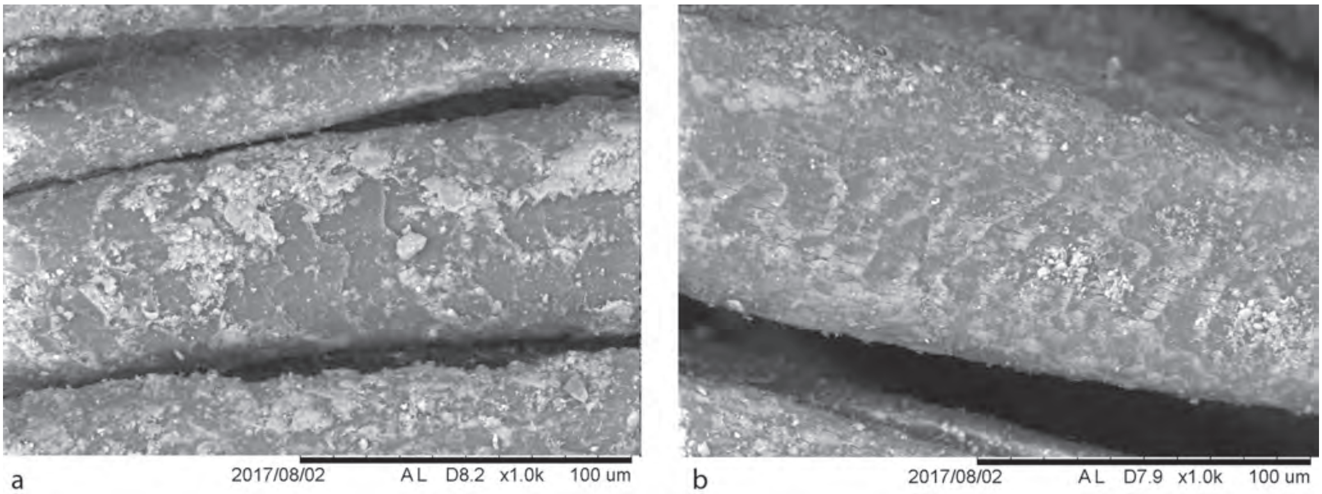

Fig. 6: SEMicrographs of fibres in Zawaydah textile fragment 676 (Images: Margarita Gleba)

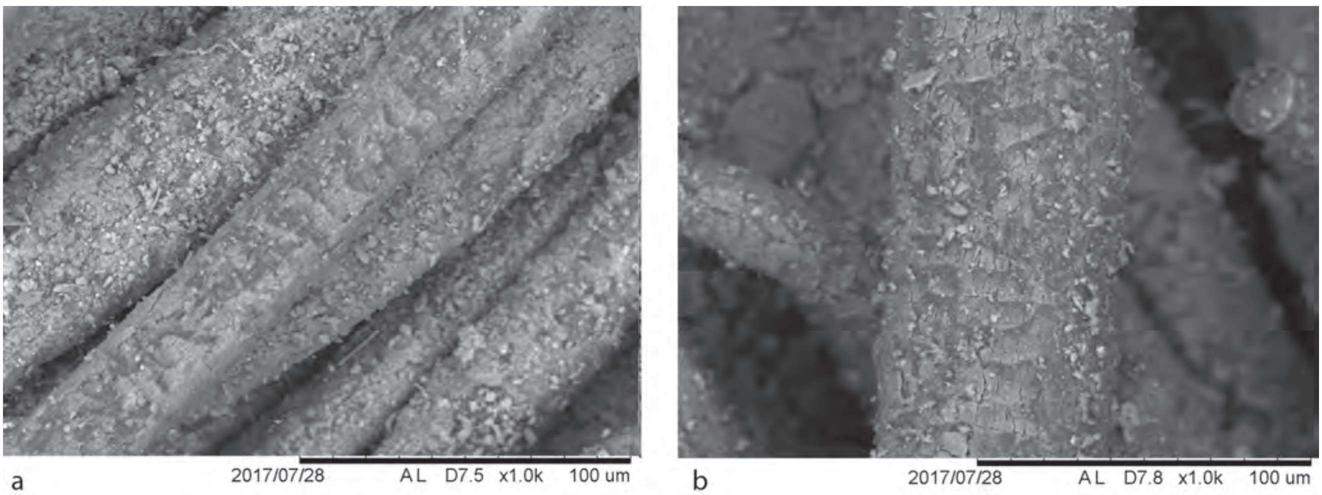

Fig. 7: SEMicrographs of fibres in Zawaydah textile fragment 852 (Images: Margarita Gleba)

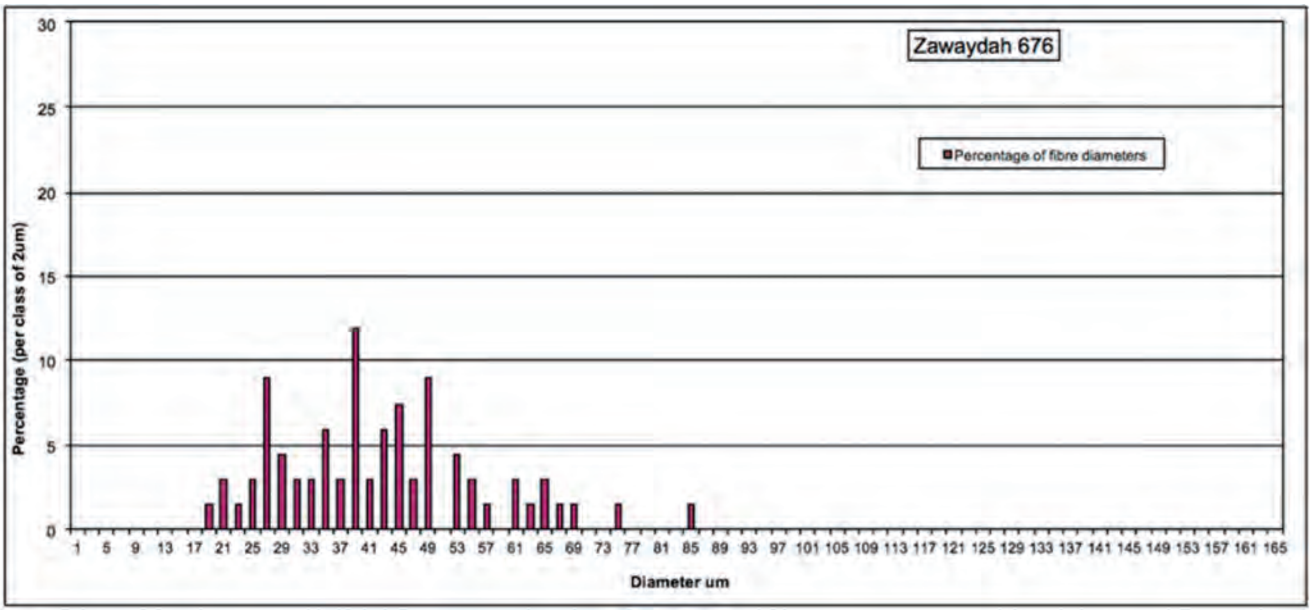

Fig. 8: Fibre diameter distribution histogram of Zawaydah 676 (Image: Margarita Gleba)

occasional S-cracks in the fibres, which suggest the S fibrillar orientation of the fibre (fig. 5) (Bergfjord & Holst 2010, 1193; Haugan & Holst 2013; Suomela et al. 2018). Fibres are still in bundles, which is typical for spliced threads (Gleba & Harris 2018).

Cuticular scales were present in fragments 676 and 852, indicating animal fibre (fig. 6 and fig. 7). Both are likely to be sheep's wool, as indicated by the irregular mosaic cuticle pattern, but differ substantially in quality, with the former having a narrower diameter range of 19 microns to 65 microns, a few coarser fibres and higher mean diameter of 42.4 microns, in comparison to the wider range of 11 microns to 113 microns (with many interruptions) and lower mean diameter of 27.3 microns in the latter (fig. 8 and fig. 9). Based on Ryder's system, fragment 676 can be classified as Hairy Medium, while fragment 852 is closer to Generalised Medium (Ryder 1964).

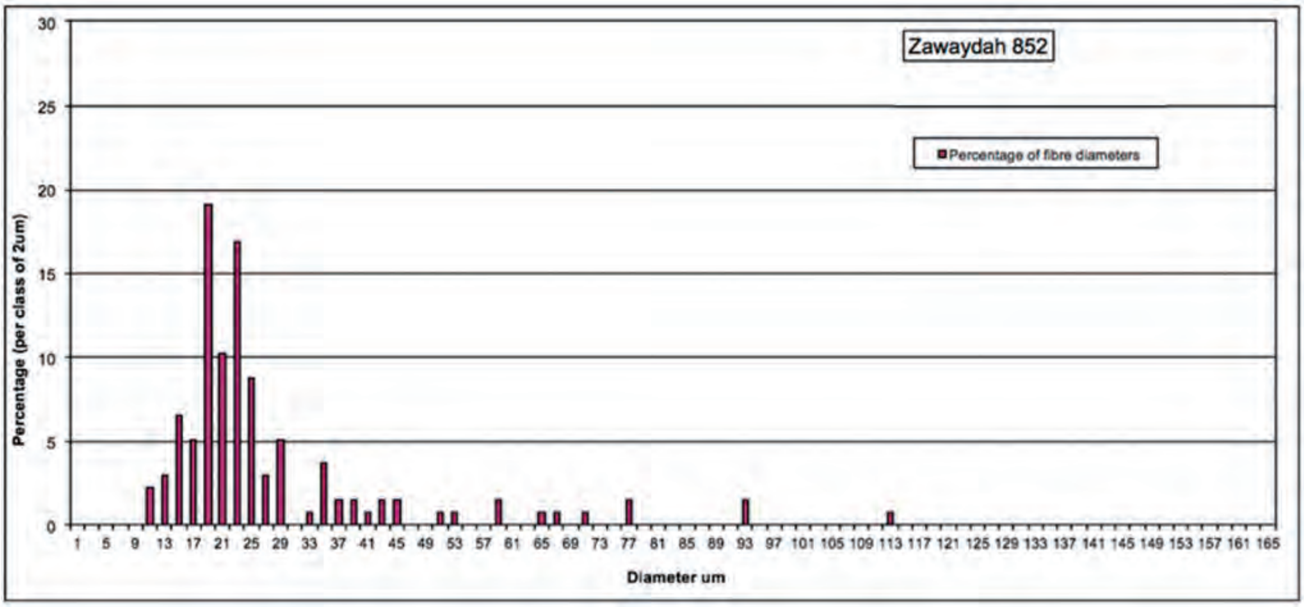

Fig. 9: Fibre diameter distribution histogram of Zawaydah 852 (Image: Margarita Gleba)

Fig. 10: Micrographs of fibres in Zawaydah: a) 676; b-c) 852, showing pigmentation (Images: Margarita Gleba)

In both cases, the wool is pigmented, ranging from brown to almost black, with larger fibres medulated (fig. 10). In 852, one of the systems is woven in darker, almost black, fibres, while the fibres in the other system range from beige (originally white?) to brown. Fragment 598, currently stored in Egypt, may also be made of animal fibre based on its macroscopic appearance and variable brown colour, but nothing more can be said about it based on the inspection of a photograph (fig. 4). Fragment 853 is made of cotton, which has long ribbon-like fibres twisting in the Z direction (fig. 11).

Dating

Fibre and structural analysis of the textile fragments from Zawaydah provided some initial indications regarding their dating. Linen textile 741, from ZWE, was the most likely of the group to date to the Predynastic period. However, given that the splicing technique continued in Egypt until about 600 BC (Granger-Taylor 1998), precise dating was not possible on the basis of structural analysis alone.

The wool fragments, also recovered in the eastern trench (ZWE), could have been Pharaonic in date but unlikely to be Predynastic, given that their wool quality was comparable to that of the textiles from the Workmen's Village at Amarna, dated to the New Kingdom (Kemp & Vogelsang-Eastwood 2001, 40-51). Nevertheless, the dating of these fragments requires further verification either by means of radiocarbon dating or by a close comparison with material coeval with most of the other finds from Zawaydah (i.e. Predynastic wool textiles). An ideal candidate for such a comparative assessment would have been a "piece of brown and white woollen knitted stuff" that Petrie reports from tomb T26 of the nearby Predynastic Cemetery T at Naqada (cf. fig. 1b; Petrie & Quibell 1896, 24) but its current whereabouts are unknown.

The cotton fragment was clearly a late intrusion in the context of its retrieval (ZWW, the western trench; cf. above), as cotton in Egypt was only introduced in the Roman era (Wild et al. 2008). Its z-twist is unusual for Egypt, where s-twist has been dominant since prehistoric times. At the same time, although z-twist is not common in Egypt until the Medieval era, z-twisted cotton textiles were imported to Egypt from India in Roman times (Kemp & Vogelsang-Eastwood 2001, 24-5; but see Wild et al. 2008, 146, for other potential sources).

As funding was available to carry out two radiocarbon dating analyses, the decision was made to date the potentially oldest (linen) and youngest (cotton) fragments. The results arising from radiocarbon dating (AMS) (fig. 12), performed at the Royal Institute for Cultural Heritage, in Brussels (Belgium), show that the linen fragment 741 can be assigned to the Middle Kingdom (circa 1980-1760 BC; cf. Hornung et al. 2006), while the cotton fragment 853 falls within the Islamic period or Middle Ages (640 AD to 1517 AD; cf.

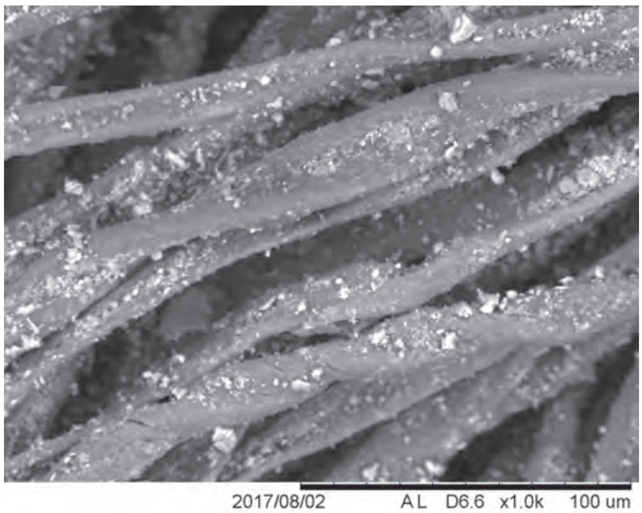

Fig. 11: SEMicrograph of fibres in Zawaydah textile fragment 853 (Image: Margarita Gleba)

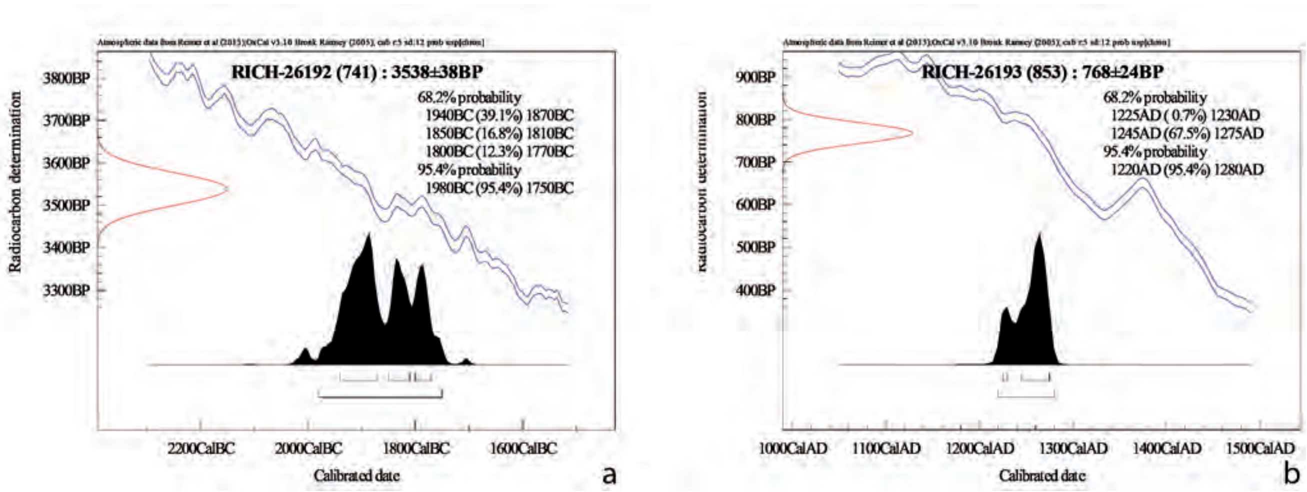

Fig. 12: a) Date of Zawaydah textile 741; b) Date of Zawaydah textile 853 (Images: Mathieu Boudin)

Petry 2008). Neither of the radiocarbon dated textile fragments from Zawaydah dates to the Predynastic times.

Discussion and conclusions

Results from the analyses conducted on four textiles from Zawaydah presented above confirm that the deposits and archaeological materials within the two main trenches excavated at the site by the IUO Expedition represent a "palimpsest" – a site with a variety of features from different periods – as already observed by the excavators and gleaned from post-excavation studies on the ceramics. Yet, the textile evidence suggests that Zawaydah had a more complex site formation and history of human activity than that reconstructed so far (i.e. two main phases ascribed to the Predynastic and the New Kingdom; see above, and Petrie & Quibell 1896, 54), and points to – at the very least – further events in site's use or frequentation in the early second millennium BC and early second millennium AD. These new data fit well within the history of the wider site of Naqada as it is understood today. However, only further in-depth research at Zawaydah itself and on the other classes of material from the site can clarify whether the textiles examined reflect isolated episodes of human presence or can be related to more substantial activity carried out at the site.

More generally, the present study reinforces the importance of detailed structural and fibre analysis of textile finds from complex archaeological contexts. Such studies can provide crucial dating information based on the technical characteristics and raw material of the finds, which may inform the decisions to carry out further analyses, such as radiocarbon dating. On the other hand, investigation of textiles is important in and of itself, as it adds to the understanding of textile history in specific geographical areas: this study offers new data that increases our current knowledge of the ancient Egyptian textile industry during the Middle Kingdom, potentially the New Kingdom and, later, Medieval times.

Acknowledgments

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Late Antique textiles from Egypt in the Ny Carlsberg Glyptotek, Copenhagen

Abstract
The Ny Carlsberg Glyptotek (NCG) possesses a small collection consisting of 13 fragments of Late Antique textiles from Egypt, possibly from the site of Akhmim. The collection primarily consists of cut-outs of decorative elements. The collection has until now not received much attention nor been thoroughly analysed. The present study seeks to remedy this neglect by performing fibre and dye analyses as well as including archival material from the museum collections.

Keywords: Late Antique textiles, Akhmim, HPLC, dye analyses, fibre analyses

Introduction
Numerous museum collections worldwide include fragments of Egyptian textiles from the Late Antique Period (circa 250 CE to 800 CE), often wrongly termed "Coptic" textiles. Late Antique textiles from Egypt were in previously thought to have been produced by Copts (Christian Egyptians), which has given them the designation "Coptic" textiles. This is, however, a misleading term since their production was not related to any specific religion or ethnicity. Neither is the "Late Roman" the chronological equivalent of what is usually meant by "Coptic". Many dated textiles formerly labelled "Coptic" in fact date to the Roman Period, the Umayyad Period in Egypt or later (Schrenk 2004). Although terminology is still an issue, the term Late Antique textiles is used here to avoid any religious or political affiliation. Many of these museum collections are published in catalogues, which were previously the dominant mode of publication, overshadowing archaeological and technical studies, which today have come to the fore (see, for example, De Moor & Fluck 2009; 2011; De Moor et al. 2007; 2013b; 2015). These collection catalogues established a strong tradition of physical description and art historical interpretation based on motifs and stylistic traits. The fragments were then categorized by their motifs, colour schemes and techniques (Thomas 2007, 139, 142). By the mid-1960s, the catalogue of "Coptic" textiles was an established genre which outlined the history of the collection, gave brief descriptions of materials and techniques followed by entries for ornamental fragments from tunics and, rarely, complete garments. The format was reinvigorated in the 1980s by an explosion of collection and exhibition catalogues that significantly altered the corpus of known works (Thomas 2007, 149). From the 1990s on, technical analyses and results from instrumental methods of analyses as well as studies of function and provenance have grown in significance in the study of these textiles.

The majority of the Late Antique textiles in the collection of the Ny Carlsberg Glyptotek (NCG) in Copenhagen, Denmark have been summarily published in a similar catalogue from 1930, including the larger part of the museum's Egyptian collection (Mogensen 1930). As several new methods of analyses have appeared since then, this paper seeks to include these and make the existence of the small NCG textile collection known and available for comparative studies.

Regrettably, many of these archaeological textiles in museum collections do not have any contextual information, which makes a thorough study of them challenging. At the end of the 19th century, astonishing amounts of textiles were unearthed in Egypt, primarily in burials at cemeteries and monasteries, but since most of the early digs and exploration campaigns (not to mention illegal looting and plundering) carried out between 1880 and the 1930s predate rigorous archaeological excavation, the majority of the early textile finds have no contextual evidence and suffer from inadequate recording (Thomas 2007, 141; Wild 2012, 17; Pritchard 2006). The first private and museum collections therefore acquired these textiles with little or no information about their archaeological context and in a fragmentary condition. Furthermore, when burials were discovered during these early explorations, the bodies were usually unwrapped after exhumation and the better preserved pieces were removed for collection. Since collectors prized colour and ornamental compositions, decorated pieces, such as panels (*tabulae*), medallions (*orbiculi),* and *clavi* were cut out and retained while the plain-woven and less well-preserved parts were usually discarded together with the bodies. As a consequence, most of the textiles from early excavations and exhumations survive as mere fragments and complete garments are rare (Thomas 2007, 141-142). Owing to the nature of early museum collecting, there are still large gaps in our knowledge on these textiles. There is, for example, no reliable way to differentiate between men's and women's garments (Bazinet 1992, 74). This underlines the necessity of further research into these artefacts.

The textiles in the Ny Carlsberg Glyptotek (NCG)

The NCG possesses a small collection of 13 fragments of Late Antique textiles, primarily consisting of cut-outs of decorative elements, which until now have not been thoroughly analysed. It is usually assumed that these kinds of textiles are made of undyed linen, while the decorative elements are of wool dyed in different colours, primarily different shades of purple (Bazinet 1992, 75; Gulmini et al. 2016, 485-86). This assumption is also based on the testimonies of ancient authors such as Herodotus, who describes how flax was used for textiles in ancient Egypt. Priests were required to wear linen garments (2.37) and linen was also the proper fibre for funerary practices, while wool was considered unclean (2.81; 2.86). The museum collection also includes three pieces of undyed linen (Schmidt 1899, catalogue number A 653; Schmidt 1908, catalogue number E 806). The textiles are however without provenance or date and have therefore been excluded from this study.

The fragments are made in the weaving techniques common in this area and period. The body of Late Roman garments and furnishing textiles were usually made in plain tabby weave in linen and wool. The fragments in the NCG collection appear to be parts of larger linen tabbies. Some of them still have part of the tabby preserved (ÆIN 952 and 960, table 1.3 and 1.10). The decorations in purple and other colours were carried out in different techniques, primarily tapestry weave, which is a weft-faced plain weave in which the dyed weft threads entirely cover the warp threads creating coloured areas of pattern and design only where needed. Additional effects are sometimes added in other techniques, such as those using a "flying shuttle" or "flying needle", intended to mimic woven ornaments. The flying shuttle technique is employed at the same time as the tapestry weave is made: a separate yarn is added to the weave with a needle, carried on the front side of the textile and sketching an image with fine lines. The thread only goes into the textile to wrap around a warp thread to secure it (Dross-Krüpe & Paetz gen. Schieck 2014, 207; Verhecken-Lammens 2013). This technique is at first sight very similar to embroidery (which was a relatively rare technique during Antiquity) but is a completely different way of decorating textiles. Embroidered textiles first appear in Egypt during the 18th Dynasty, but it is not until the Hellenistic and Early Roman period that embroidery can be identified again. The number of embroidered textiles slightly increases during Late Roman times, but they are not common until the Byzantine and Early Islamic period, when embroidery becomes one of the most frequently employed decorative textile techniques (Dross-Krüpe & Paetz gen. Schieck 2014).

Pile weaving was also used. Weft-looping is the most common type. It introduces a doubled or trebled strand of linen (or wool), edge to edge (although looping threads can also be introduced locally), in one of the plain weave sheds, while pulling out a length of this extra weft between warp threads at regular or irregular intervals to an even length. When long, the loops look like a fringe. Only one of the textiles studied here is made using this technique (ÆIN 1021, table 1.12).

Provenance

A total of 12 of the textiles (ÆIN 949, 950, 952-960 and 960bis, Table 1.1-1.11) were acquired by the museum via the art market in 1906 from the Danish art historian and Egyptologist Henry Madsen (1881-1921), who lived in Paris from 1905 to 1908. He was a student of H. O. Lange and had a short career in

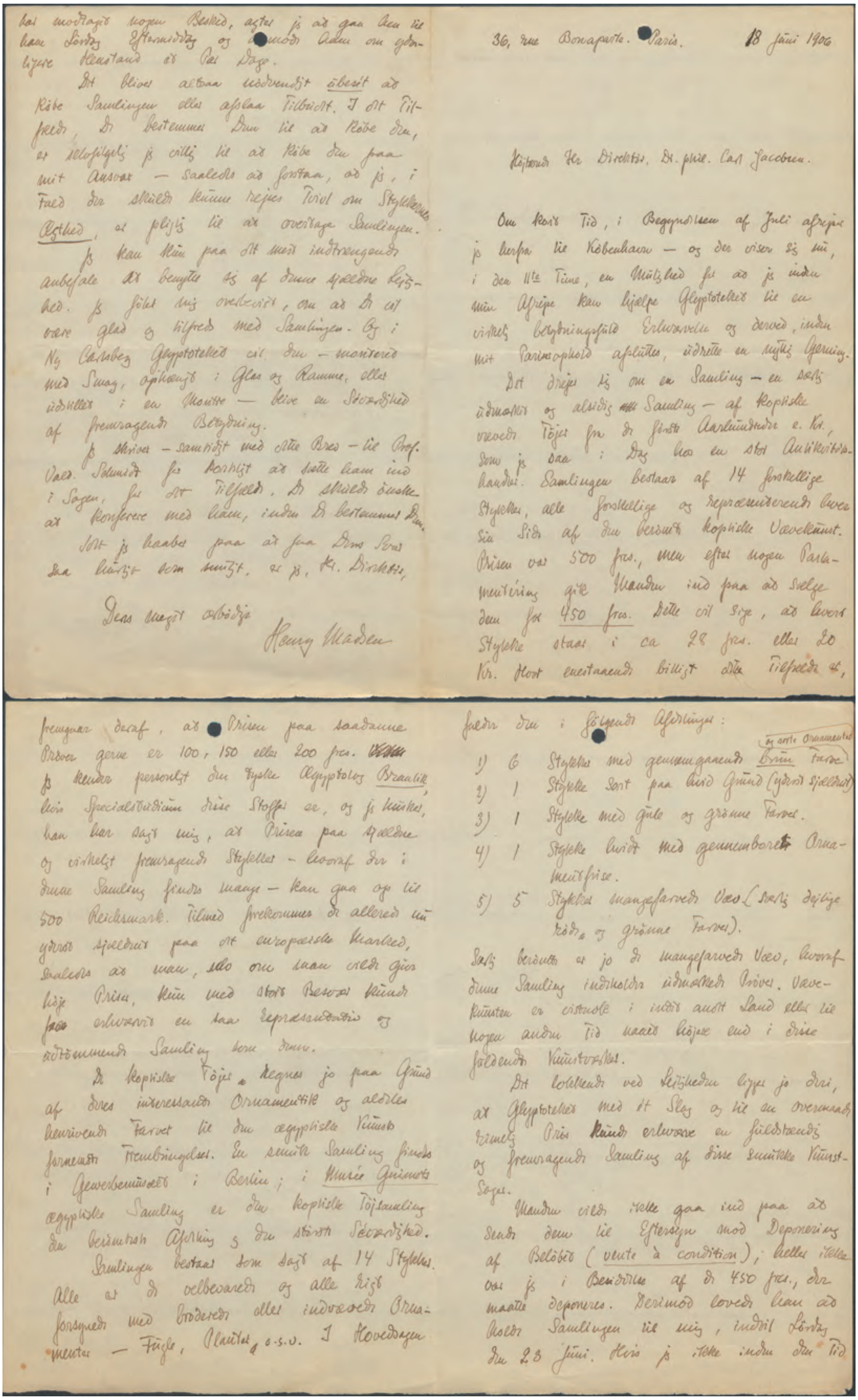


Fig. 1: Photograph and translation of the letter from Henry Madsen to Carl Jacobsen, dated 18 June 1906 (Image and translation: Cecilie Brøns)

To: The Highly-Esteemed Carl Jacobsen

In a short while, at the beginning of July, I shall be departing from here for Copenhagen – and it appears that, at the 11th hour, there is the possibility that I can help the Glyptotek in making a really significant acquisition and thereby do something useful before the end of my stay in Paris.
It is the question of a collection – a particularly remarkable and very varied collection – of Coptic woven garments from the first century AD, which I saw today on the premises of a major dealer in antiquities. The collection consists of 14 separate pieces, all different and each representing an aspect of the renowned Coptic art of weaving. The price was 500 francs, but after some negotiation the man agreed to drop this to 450 francs. That means that each item is going for 28 fr. or 20 kr. How cheap this is becomes apparent when one compares the price of samples of such work which can be as high as 100, 150 or 200 fr.
I am personally acquainted with the German Egyptologist Braulik, whose special field of study these fabrics are, and I remember him telling me that the price of such rare and truly excellent pieces – of which there are many in this collection – can go as high as 500 Reichsmarks. Add to this the fact that already they only appear extremely rarely on the European market, so that even if one desired to offer high prices one could only acquire such a representative and exhaustive collection as this with considerable difficulty.
Because of their interesting ornamentation and absolutely ravishing colours, the Coptic garments are reckoned as the most illustrious creations of Egyptian art. One beautiful collection is to be found in the Gewerbemuseum in Berlin; in the Musée Guimet's Egyptian collection, the collection of Coptic costume is the most famous department and the greatest "attraction".

The collection, as I said, consists of 14 pieces. All are well-preserved and richly decorated with embroidered or woven-in ornaments – birds, plants etc. In principle, it falls into the following divisions:

1) 6 pieces with a brown colour throughout and black ornaments.
2) 1 piece with black on white ground (extremely rare)
3) 1 piece with yellow and green colours
4) 1 piece white shot through with ornamental frieze
5) 5 pieces of multi-coloured weave (especially lovely red and green colours)

Particularly renowned is the multi-coloured weave, of which this collection contains remarkable samples. The art of weaving has certainly never been raised to greater heights in any other country or at any other time than in these consummate works of art.
What is enticing about this opportunity is that, at a stroke, the Glyptotek could acquire a complete, exciting collection of these beautiful works of art at an exceedingly reasonable price.
The man was not prepared to agree to send them for inspection against the paying of a deposit (*vente à condition*); neither was I in possession of the 450 francs, the deposit of which was required. On the other hand, he promised to hold the collection for me until Saturday 23 June. If before that time, I have not received any communication I intend to go to him on Saturday afternoon and ask him to give me a few more days.
It will, therefore, be necessary to buy the collection unseen or miss out on the offer. In the event of your deciding to buy them, I am of course prepared to buy them at my own risk – on the understanding that, should any doubts be raised about the *authenticity* of the items, I am obliged to take over the collection.
I can only recommend in the strongest terms the making use of this rare opportunity. I feel certain that you will be happy and satisfied with the collection. And that installed in the Glyptotek, tastefully mounted, hung behind glass in frames or exhibited in a glass case – they will be an attraction of truly great consequence.
Together with this letter, I enclose one to Professor Valdemar Schmidt giving him a quick apprisal of the situation in case you wish to confer with him before making your decision.
Hoping to receive your answer as quickly as possible, I remain, Herr Director,

Your devoted

Henry Madsen

Egyptology, publishing about 16 articles, but he never conducted any excavations in Egypt (Hagen & Ryholt 2016, 122).

The last textile (ÆIN 1021, Table 1.12) was given to the museum as a gift in 1908 by Emile Guimet, founder of the Museé Guimet in Paris. The museum archives have revealed a letter from Henry Madsen to Carl Jacobsen from June 1906 wherein Madsen enthusiastically tries to convince Jacobsen to buy the collection of textiles from an unknown art dealer in Paris for the price of 450 francs (fig. 1). Henry Madsen's letter mentions 14 textiles, but only 13 were included in the museum's collections.

According to the museum records, the textiles are from the cemeteries of ancient Panopolis, the modern city of Akhmim, on the east bank of the Nile in Upper Egypt. The city was known as Panopolis in Greek, and later, Shmin in Coptic. According to Strabo (*Geography* XVII, 41), Akhmim/Panopolis was a well-known production centre for linen fabrics from Pharaonic times. Up to now, there has been little literary evidence of textile production at the site throughout the Late Antique Period, although some documents attest textile specialists worked in the city during the fourth century CE and an inscription on a rug from the Islamic Period confirms that Akhmim remained a centre of textile production in Islamic times (Fluck 2008, 211).

The excavations of the three major cemeteries at Akhmim were conducted over several years beginning in 1884 by the team of the French Egyptologist and director of the Cairo Museum Gaston Maspero (Pritchard & Verhecken-Lammens 2001, 21). Enormous quantities of textiles were uncovered. Akhmim is generally considered one of the major find-spots in Egypt for textiles of the first millennium CE and it has been claimed that there is no doubt that most of the textiles circulating in the late 19th century, specifically in the years 1885 to 1886, when the excavations led by Maspero took place, came from this site, particularly from the al-Hawawis necropolis, placed northeast of the city. Thus, inspired by Maspero's finds, other contemporary scholars and collectors such as Vladimir G. de Bock, Theodor Graf, Carl Schmidt, and Robert Forrer visited the site to purchase textiles, many of which ended up in museum and private collections (Fluck 2008, 212-213). However, Akhmim became well known as a source of Late Antique and Early Islamic textiles and the toponym Akhmim may have been given to objects, especially textiles, which did not come from the site (O'Connell 2008). Thus, it is not certain that the textiles in the NCG are from this particular site.

Dating

Dating the textiles is a complicated issue as discussed by scholars elsewhere (De Moor et al. 2007). The lack of known find contexts for these textiles makes dating extremely complicated. Previous scholarship has therefore tended to base the chronology of these textiles on iconographical and stylistic comparisons with other artefacts such as mosaics, paintings or sculptures. Since the textiles appear to have been less influenced by artistic and technical changes than other art forms, stylistic dating methods are generally vague and highly subjective (Cabrera & Rodríguez 2007, 136-37; De Moor et al. 2007, 9). Radiocarbon dating has become more common, but this method of dating is not without complications either. A high level of purity in the sample is necessary, i.e. no contamination, which is sometimes not possible. Most importantly, however, the method requires sample material and is destructive. Although sample sizes for radiocarbon dating have decreased significantly over the years, sampling is often not possible due to the state of preservation of the textiles. Owing to the state of the NCG textiles, it has not been deemed possible to take an extra sample of each for radiocarbon dating.

The database of radiocarbon-dated textiles, run by the University of Bonn, is therefore an extremely helpful tool when seeking to date fragile, archaeological textiles, since it provides easy access to reliably dated textiles from the first millennium BCE and CE (Internet source 1). Luckily, during the last few decades, a number of textiles have been radiocarbon dated, which provides expanding possibilities for comparison.

Four of the NCG textiles (ÆIN 950, 952, 953, and 955) are quite similar with regard to decoration, motifs as well as technique and colour. All four pieces correspond to parallels, which have been radiocarbon dated. Three similar medallion pieces from unknown sites in Egypt (now in the Musée du Louvre) thus provide reliable comparison for dating the NCG textiles. One is a weft-looped linen tabby with decoration in tapestry weave, dated to 1750 ±35 BP (calibrated calendar date: 2σ 211 AD [92.8%] 395 AD) (Internet source 2). A second, which is also a tapestry weave in linen and wool, is dated to 1720 ± 30 BP (calibrated calendar date: 2σ 248 AD [95.4%] 390 AD) (Internet source 3). A third, which is also a tapestry weave in linen and wool, is dated to 1610 ±25 BP (calibrated calendar date: 2σ 403 AD [95.4%] 536 AD) (Internet source 4). A final example for comparison, provided by the database, is a linen tabby with tapestry woven decoration in wool from Antinoe/Antinoupolis/Shech Abade and now in the Museu del Monasteri de Montserrat. The piece has been dated to 1770 ±40 BP (calibrated calendar date:

2σ 134 AD [93.3%] 352 AD) (Internet source 5). A likely parallel for ÆIN 949 is another piece from the Musée du Louvre. It is a tabby with decoration in tapestry weave from an unknown site in Egypt. It has been radiocarbon dated to 1560±35 BP (calibrated calendar date: 2σ 419 AD [95.4%] 574 AD) (Internet source 6). Another possible parallel for ÆIN 949 (although in a different colour) is a fragment of a breast panel in tapestry weave of a tunic, now in a private collection. It showed a radiocarbon age of 1653 ±54 BP (Paetz gen. Schieck 2007, 169).

A linen textile with brocaded, geometric pattern in wool from Arsinoë/Krokodilopolis is very similar to ÆIN 956 and 957. The brocaded parts have been radiocarbon dated to the period from 660 to 780 AD, which thus provide a possible parallel date for the two NCG pieces (Fluck & Mälck 2007, 158-59) (Internet source 7).

The two bands ÆIN 958 and 956 have been variously dated. According to Mogensen, they belong to the eighth or ninth century AD (Mogensen 1930, 79, Cat. A 626). Spies, on the other hand, suggests a date in the 14th or 15th century AD, based on similarities with tablet-woven bands used to decorate ecclesiastical vestments belonging to the period from the eighth to the 16th century AD (Spies 2000, 218). But, no radiocarbon dating has been performed, and the question must, for now, remain open.

The dates given in table 1 are the stylistic dates estimated by Mogensen, who briefly dealt with the textiles in her publication in 1930, as well as the dates provided by comparison with similar radiocarbon-dated textiles (where possible).

Dye analyses

Detailed information on the dye composition – and therefore on the original appearance and connotations of the ancient textiles – is obtainable via high performance liquid chromatography (HPLC). This method has, until now, allowed for the identification of the largest number of colourants in art and textile objects (Pozzi et al. 2012, 185). Over the last few decades, a large number of Egyptian textile finds from different sites and a wide timespan has been analysed for dyes. These have revealed more and more information about dye traditions, the provenance and the exchange of dyes, and the complexity of dye technology in Egypt (De Moor et al. 2010, 2013a; Vanden Berghe 2017b, 2016b and 2011; Van Strydonck et al. 2011; Wouters et al. 2008). The dye investigations made it clear that a very restricted palette of dye sources was used until the seventh century AD. Madder root for red, indigo or woad as a vegetal source for blue, and a luteolin-based dye plant, weld or an equivalent such as sawwort, dyer's greenweed or chamomille, for yellow being most prominent. In addition, a few identifications show the use of kermes, cochineal, lichen and muricid purple. A good knowledge of yarn and fleece dyeing, frequently using a combination of different dyes and multi-step processes with combinations of mordant and vat dyes, compensated for the limited range of dye sources. In addition, a range of metal mordants was used to produce even more shades. New dye sources such as sappan wood (also known as redwood), young fustic and Indian lac were added to the existing palette or used as substitutes after the Islamic conquest of Egypt in the middle of the seventh century AD, owing to political and economic changes and the emergence of new trade routes (Forbes 1956; Vanden Berghe, 2011, 2017b; Wouters et al. 2008). The discovery of Indian lac in Egyptian textiles was further refined to the period between the last quarter of the seventh century and the last quarter of the ninth century AD (De Moor et al. 2017).

The knowledge gained on the use of dyes and dyeing techniques in specific groups of firmly dated Egyptian textiles makes it increasingly possible to link identified dye sources to dating and/or origin, provided that the analytical technique used is highly sensitive and selective. The technique must permit a separation between chemically very closely related dye molecules. It must also permit detection of and distinction between components present in large and small quantities because the latter is often important for detailed specification of the dye source. So far, despite promising progress in the field, this is still a major challenge for many non-destructive spectroscopic techniques compared to chromatographic separation techniques. Dye identification has been performed with HPLC in all cases where sampling was possible.

Methodology

Samples of 3 mm to 5 mm of threads were taken from most of the textiles. Organic dyes were identified using HPLC with photo diode array detection (HPLC-DAD) (Vanden Berghe 2016a and 2017a). In the cases of ÆIN 950, 952, 958, 959, and 960bis it was not possible to remove fibres of the relevant hues without causing damage to the weave. ÆIN 957 was not sampled either since it is represented by its counterpart ÆIN 956. The HPLC analysis therefore included red and purple fibres from ÆIN 949, 953-956, and 960 as well as bluish-black fibres from ÆIN 1021. In a few instances, including ÆIN 960bis, blue and yellow fibres were

ÆIN 949 (Mogensen A 618) Small square decorative element (*tabula*) probably from a tunic. The woven decoration depicts a standing male figure raising his left arm in the air and holding a hare in his right hand. Branches and leaf ornaments fill the background. Measurements: H. 6.7 cm, W. 6.5 cm. Technique: Eccentric tapestry and flying shuttle technique. Date: 4th – 5th century CE (Mogensen) 14C dated parallels: 1560±35 BP (calibrated calendar date: 2σ 419 CE (95.4%) 574 CE). Dyes: Mollusc purple Fibre: Wool	
ÆIN 950 (Mogensen A 614) Oval purple medallion (*orbiculus*) richly ornamented with different patterns in white thread. Along the edge of the medallion is a border in a wave pattern. Measurements: W. 30.8 cm, H. 25 cm. Technique: Eccentric tapestry and flying shuttle technique. Date: 3rd – 4th century CE (Mogensen) 14C dated parallels: 1: 1750 ±35 BP (calibrated calendar date: 2σ 211 CE (92.8%) 395 CE). 2: 1720 ± 30 BP (calibrated calendar date: 2σ 248 CE (95.4%) 390 CE). 3: 1610 ±25 BP (calibrated calendar date: 2σ 403 CE (95.4%) 536 CE). 4: 1770 ±40 BP (calibrated calendar date: 2σ 134 CE (93.3%) 352 CE). Dyes: N/A Fibre: Wool	
ÆIN 952 (Mogensen A 619) Purple, circular medallion (*orbiculus*) sewn onto a support of yellowish linen fabric. It is not possible to determine whether the current mounting is original. Measurements: W. 15 cm, H. 15.5 cm. Technique: Weft-faced, plain weave with decoration in flying shuttle technique. Date: 3rd – 4th century CE (Mogensen) 14C dated parallels: 1: 1750 ±35 BP (calibrated calendar date: 2σ 211 CE (92.8%) 395 CE). 2: 1720 ± 30 BP (calibrated calendar date: 2σ 248 CE (95.4%) 390 CE). 3: 1610 ±25 BP (calibrated calendar date: 2σ 403 CE (95.4%) 536 CE). 4: 1770 ±40 BP (calibrated calendar date: 2σ 134 CE (93.3%) 352 CE). Dyes: N/A Fibre: N/A	

Table 1: Description of the textiles in the Ny Carlsberg Glyptotek collection, Copenhagen, Denmark (Images: Pernille Klemp)

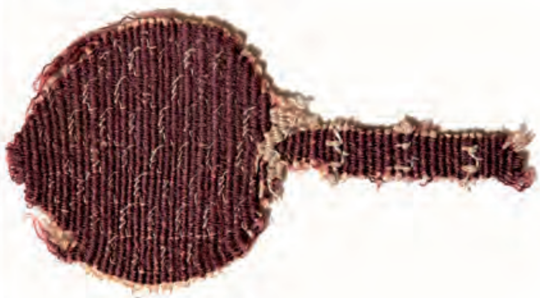
ÆIN 953 (Mogensen A 616) Dark purple, square piece of decoration (tabula) from a tunic. Central square decoration made of fine windings of white thread. Along the edge, a wide border made in a similar pattern forms a fine frame. Measurements: W. 27 cm, H. 28 cm. Technique: Weft-faced, plain weave with decoration in flying shuttle technique. Date: 3rd – 4th century CE (Mogensen) 14C dated parallels: 1: 1750 ±35 BP (calibrated calendar date: 2σ 211 CE (92.8%) 395 CE). 2: 1720 ± 30 BP (calibrated calendar date: 2σ 248 CE (95.4%) 390 CE). 3: 1610 ±25 BP (calibrated calendar date: 2σ 403 CE (95.4%) 536 CE). 4: 1770 ±40 BP (calibrated calendar date: 2σ 134 CE (93.3%) 352 CE). Dyes: Madder. Fibre: Wool	
ÆIN 954 (Mogensen A 620) Purple band (clavus) from a tunic. Meander-shaped decoration in fine, white yarn. Measurements: W. 5.7 cm, L. 31.7 cm. Technique: Weft-faced, plain weave with decoration in flying shuttle technique. Date: 4th – 5th century CE (Mogensen) 14C dated parallels: N/A Dyes: Greyish purple: indigo/woad and madder. Fibre: Wool	
ÆIN 955 (Mogensen A 617) The small fragment has the shape of a pomegranate. It originally belonged to the decoration of a tunic. Quite fine, white yarns are woven onto the violet background. A stalk completes the leaf. Measurements: W. 4.9 cm, H. 9.1 cm. Technique: Weft-faced, plain weave with decoration in flying shuttle technique. At the touch point of shaft and medallion is a small area of eccentric tapestry. Date: 4th – 5th century CE (Mogensen) 14C dated parallels: 1: 1750 ±35 BP (calibrated calendar date: 2σ 211 CE (92.8%) 395 CE). 2: 1720 ± 30 BP (calibrated calendar date: 2σ 248 CE (95.4%) 390 CE). 3: 1610 ±25 BP (calibrated calendar date: 2σ 403 CE (95.4%) 536 CE). 4: 1770 ±40 BP (calibrated calendar date: 2σ 134 CE (93.3%) 352 CE). Dyes: indigo/woad and madder. Fibre: Wool	

Table 1 (Continued): Description of the textiles in the Ny Carlsberg Glyptotek collection, Copenhagen, Denmark (Images: Pernille Klemp)

ÆIN 956 (Mogensen A 621) Rhomboid fragment with geometric star-shaped ornament in red and yellow. Measurements: W. 16.5 cm, H. 15.4 cm. Technique: Plain weave with brocaded decoration. On top of the ground weave a coloured pattern weft is inserted after every second change of the sheds. Date: 7th – 8th century CE (Mogensen) 14C dated parallels: 660 to 780 CE Dyes: Greenish blue: indigo/woad and a yellow dye source (weld, sawwort, dyer's greenweed or chamomile). Orange/red: madder. Fibre: Wool	
ÆIN 957 (Mogensen A 622) Very similar fragment to the above, but less well-preserved. Probably originally part of the same textile. Measurements: W. 19.5 cm, H. 15.8 cm. Technique: Plain weave with brocaded decoration. Date: 7th – 8th century CE (Mogensen) 14C dated parallels: 660 to 780 CE Dyes: (see ÆIN 956). Fibre: N/A	
ÆIN 958 (Mogensen A 625) Band with geometric decoration in many colours. Measurements: W. 2.5 cm, L. 48.5 cm. Technique: Tablet weaving. The decoration is made in supplementary weft brocading (broché). Number of tablets: 34 (7 in each border, 20 in central section). Brocade pattern: On front only. Borders: Straight lines. Centre section: Diamond-filled triangles separated by areas of 3 diagonals. Warp: White linen: S-spun, Z-plied. Wool: S-spun, single thread (not plied). Weft (ground): White linen, S-spun, single thread (not plied). Weft (brocade): Borders brocaded with ground weft; centre section brocaded with dyed wool. Wool: loose to no spin, probably 2-ply. Date: Mogensen suggests a date in the 8th or 9th century CE, while Spies suggests a date in the 14th or 15th century CE (Spies 2000, 218). 14C dated parallels: N/A Dyes: N/A Fibre:N/A	

Table 1 (Continued): Description of the textiles in the Ny Carlsberg Glyptotek collection, Copenhagen, Denmark (Images: Pernille Klemp)

ÆIN 959 (Mogensen A 626) Identical band to the above. The two bands originally belonged together. Measurements: W. 2.5 cm, L. 48.5 cm. Technique: Same as ÆIN 958. Date: Mogensen suggests a date in the 8th or 9th century CE, while Spies suggests a date in the 14th or 15th century CE (Spies 2000, 218). 14C dated parallels: N/A Dyes: N/A Fibre: N/A	
ÆIN 960 (Mogensen A 624) Fragment with woven decoration in the shape of a red leaf with a stem. A female figure, possibly a mermaid, rendered in different colours is depicted inside the leaf. Measurements: W. 14 cm, H. 20 cm. Technique: Tapestry weave with eccentric wefts and lazy lines. Date: 6th – 7th century CE (Mogensen) 14C dated parallels: N/A Dyes: Orange/red: madder; Dark blue: indigo/woad and madder; Yellow: madder and a yellow dye source (weld, sawwort, dyer's greenweed or chamomile). Fibre: Wool	
ÆIN 960bis (Mogensen A 623) Small, oval medallion (orbiculus). The symmetric pattern is unusual for late Roman textiles. Measurements: W. 10.3 cm, H. 7.3 cm. Technique: Eccentric tapestry (yellow warp and blue weft). Date: 5th century CE (Mogensen). 14C dated parallels: N/A Dyes: indigo/woad and lichen dyes (?). Fibre: Wool	
ÆIN 1021 (not included in Mogensen) Large rectangular fragment with a dark, almost black decoration in the shape of a swastika. Measurements: W. 53 cm, H. 33 cm. Technique: Plain weave with loop piling. The dark stripe is weft-faced, plain weave with three threads in every shed. The remaining part of the textile is woven in 1/1 plain weave. The decoration is brocaded into the weave with simple weft loops. Date: unknown 14C dated parallels: N/A Dyes: Indigo/woad and small amount of madder. Fibre: Wool	

Table 1 (Continued): Description of the textiles in the Ny Carlsberg Glyptotek collection, Copenhagen, Denmark (Images: Pernille Klemp)

Inv. no.	Colour	Dye composition
ÆIN 949	Purple	52 6-monobromoindigotin, 27 indigotin, 21 6,6'-di brominated indigotin (DMSO, 255 nm) 39 6-monobromoindigotin, 34 indigotin, 27 6,6' -di brominated indigtotin (DMSO, 288 nm)
ÆIN 953	Red	81 purpurin, 18 alizarin, 1 munjistin (HCl, 255 nm)
ÆIN 954	Greyish blue	69 indigotin, 20 alizarin, 10 purpurin, 1 indirubin (DMSO, 255 nm) 63 purpurin, 37 alizarin (HCl / DMSO, 255 nm)
ÆIN 955	Red	58 indigotin, 34 alizarin, 8 purpurin (DMSO, 255 nm) no dyes detected (HCl) [Note: extremely small sample size]
ÆIN 956	Greyish blue	92 indigotin, 2 indirubin, 2 luteolin, 2 luteolin-7-0-glucoside, 2 apigenin-7-0-glucoside (DMSO, 255 nm)
ÆIN 956	Orange red	51 purpurin, 46 alizarin, 3 munjistin, 1 anthragallol (HCl, 255 nm)
ÆIN 960	Blue	36 alizarin, 32 indigotin, 29 purpurin, 2 luteolin, 1 anthragallol (HCl, 255 nm)
ÆIN 960	Red	91 purpurin, 9 alizarin (HCl, 255 nm)
ÆIN 960	Yellow	38 luteolin, 38 alizarin, 24 purpurin (HCl, 255 nm)
ÆIN 960b	Blue	100 indigotin (DMSO, 255 nm and 288 nm) 100 indigotin (HCl, 255 nm) 98 indigotin, 2 indirubin (HCl, 288 nm)
ÆIN 1021	Bluish black	85 indigotin, 8 alizarin, 5 purpurin, 2 indirubin (DMSO, 255 nm) 66 purpurin, 18 alizarin, 16 indigotin (HCl, 255 nm)
ÆIN 1021	Black	8 munjistin, 34 alizarin, 6 indigotin, 52 purpurin (DMSO, 255 nm)

Table 2: HPLC-DAD results. Percentages of the detected dye molecules in the acidic (HCl) or solvent (DMSO) extract, calculated after the relative ratios of the peak areas measured at the indicated wavelength (nm)

included in the analysis for comparison. Prior to the chromatographic analysis, the samples were examined under a microscope in order to determine the colour of the fibres and to remove potential contamination.
The chromatographic analyses were done with HPLC equipment Alliance and photo diode array detector from Waters (USA). Identification of the dye molecules is done based on comparison of both absorbance spectrum and retention time with spectra from the in-house reference library of natural and synthetic organic dyes. The colourants were recovered from the fibres using either strong acidic extraction with hydrochloric acid whereas dimethyl sulfoxide was used in particular for the bluish and black samples. A detailed analytical protocol for this is published elsewhere (Vanden Berghe et al. 2009).

Results

The dye molecules identified after chromatographic analysis are listed in table 2. The detection of the anthraquinone dye compounds alizarin, purpurin, anthragallol and munjistin is indicative of the use of the roots of the madder plant (*Rubia tinctorum* L.) as a red dye source. Indigotin and indirubin are the marker compounds for blue dyeing with indigo (*Indigofera sps.*) or woad (*Isatis tinctoria* L.). They are formed through fermentation from the precursors naturally occurring in these plants (Gulmini et al. 2013, 137). It is not

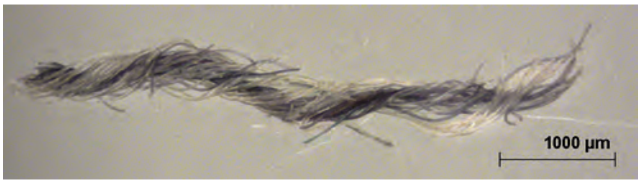


Fig. 2: Micrograph of purple thread from ÆIN 949 (Image: images@KIK-IRPA)

possible to distinguish between the two plant sources since indigotin is the main chromophore in both of them (Pozzi et al. 2012, 189). Thus, the HPLC results can only show the presence of indigotin, but not the origin, making it impossible to distinguish between indigo and woad from the dye composition. When brominated indigoid dye molecules are detected, an indigoid source of animal origin, known as muricid purple, has been applied. Luteolin, apigenin and their glucosides are flavonoid compounds suggesting the use of a yellow dye source, such as weld (*Reseda luteola* L.), sawwort (*Serratula tinctoria* L.), dyer's greenweed (*Genista tinctoria* L.), chamomile (*Anthemis sps.*) or another equivalent.

Microscopic examination of the purple yarn from ÆIN 949 shows that the thread is composed of white-undyed, and blue-dyed fibres indicative for yarn production with a mixture of undyed and fleece-dyed fibres (fig. 2). The HPLC analyses revealed that the blue fibres were dyed with real purple from molluscs. The red/brown yarns from ÆIN 953 are dyed with madder, while the dark red/purple threads from ÆIN 955 were achieved by dyeing with a combination of indigo/woad and madder. Fragment ÆIN 954 is made of more greyish-purple threads, dyed with a combination of indigo/woad and madder. From fragment ÆIN 956, greenish-blue and orange/red yarns were investigated. The greenish-blue is the result of the use of a combination of indigo/woad and a yellow dye source, which might be weld, sawwort, dyer's greenweed or chamomile. The orange red is obtained with madder.

Fragment ÆIN 960 contains a pattern made of orange/red, dark blue and yellow threads. Madder was applied for the red colour, indigo/woad and madder to produce the blue shade and the yellow was obtained with the combination of madder and a yellow dye source again either weld, sawwort, dyer's greenweed or chamomile.

By examination of the bluish fibres from fragment ÆIN 960bis under magnification, they appear to be composed of blue, reddish and uncoloured fibres suggesting yarn production with a mixture of different fleece-dyed and undyed fibres (fig. 3). The identified dye compounds of the two analysed extracts (table 2) only refer to dyeing with woad/indigo, while any evidence of a red dye compound is lacking. Moreover, the red dye is extremely light sensitive, as complete fading of the red colour is observable during the microscopic examination of the sample. As a result, it can be suggested that lichen dyes might have been used.

From fragment ÆIN 1021, dark bluish and black threads were analysed. The dark, bluish black fibres have been dyed with woad or indigo and a minor amount of madder. Dye compounds from the same dye sources are also present in the black threads but the small amounts detected in the black excludes that the black colour is the result of dyeing alone. Possibly condensed tannin not detectable with HPLC was added to produce the dark shade but it is even more likely that naturally pigmented wool fibres were used.

The identified dye sources present in the Late Antique textiles under investigation are madder, indigo or woad and weld or an equivalent yellow dye such as sawwort, dyer's greenweed or chamomile. Several yarns described as purple, blue, greyish or blackish-blue and red are dyed by the combination of a vegetal indigoid dye, top dyed with red mordant dyes from the roots of madder (*Rubiaceae* family), the most common way to create purple shades in the Roman and later "Coptic" periods. The purple yarns from textile ÆIN 960bis were dyed with indigo/woad together with lichen. One textile fragment, textile ÆIN 949, is created with a purple configuration made of "true purple", obtained by the use of seashells. Such muricid purple dyeing is identified rarely in Egyptian textiles and can be considered as direct

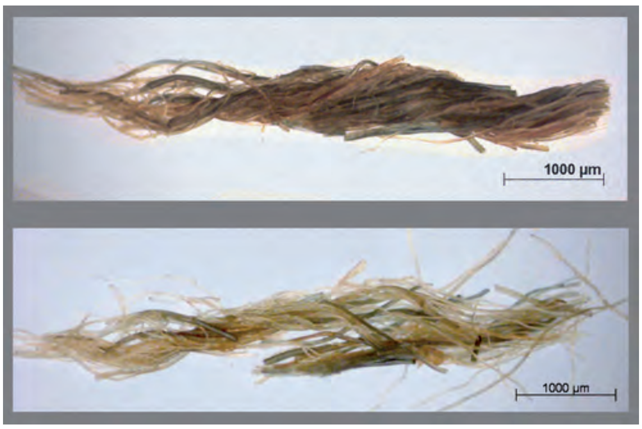


Fig. 3: Micrographs of fading red colour in blue thread from ÆIN 960bis. Top: Colours observed initially. Bottom: The red colour is no longer visible after five minutes (Images: images@KIK-IRPA)

evidence of the extremely high value of that textile fragment (Vanden Berghe 2011; De Moor et al. 2010; Wouters 2009; Wouters et al. 2008).

Fibre analyses

Although the coloured yarns in these kinds of weaving are usually made from wool, nine textiles were selected for fibre analyses to verify this. In the cases of ÆIN 952, 958, 959 it was not possible to remove fibres of the relevant hues without causing damage to the weave. ÆIN 957 was not sampled since it is represented by its counterpart ÆIN 956. Thus, the fibre analysis included coloured fibres from ÆIN 949, 950, 953-956, 960, and 960bis, as well as from ÆIN 1021. Two samples were taken from ÆIN 956, one of the blue fibres and one of the red fibres, as well as from ÆIN 960. Thus, 1 mm to 2 mm of thread was cut from each of 11 yarns in nine textiles. The analyses were carried out with a Primo Star iLED microscope from Zeiss equipped with and AxioCam ERc5s camera. The fibres from each of the selected yarns were spread on to microscope slides using liquid paraffin for mounting and viewed in longitudinal sections using a 10 x objective (circa 100 x magnification) and digitally photographed for

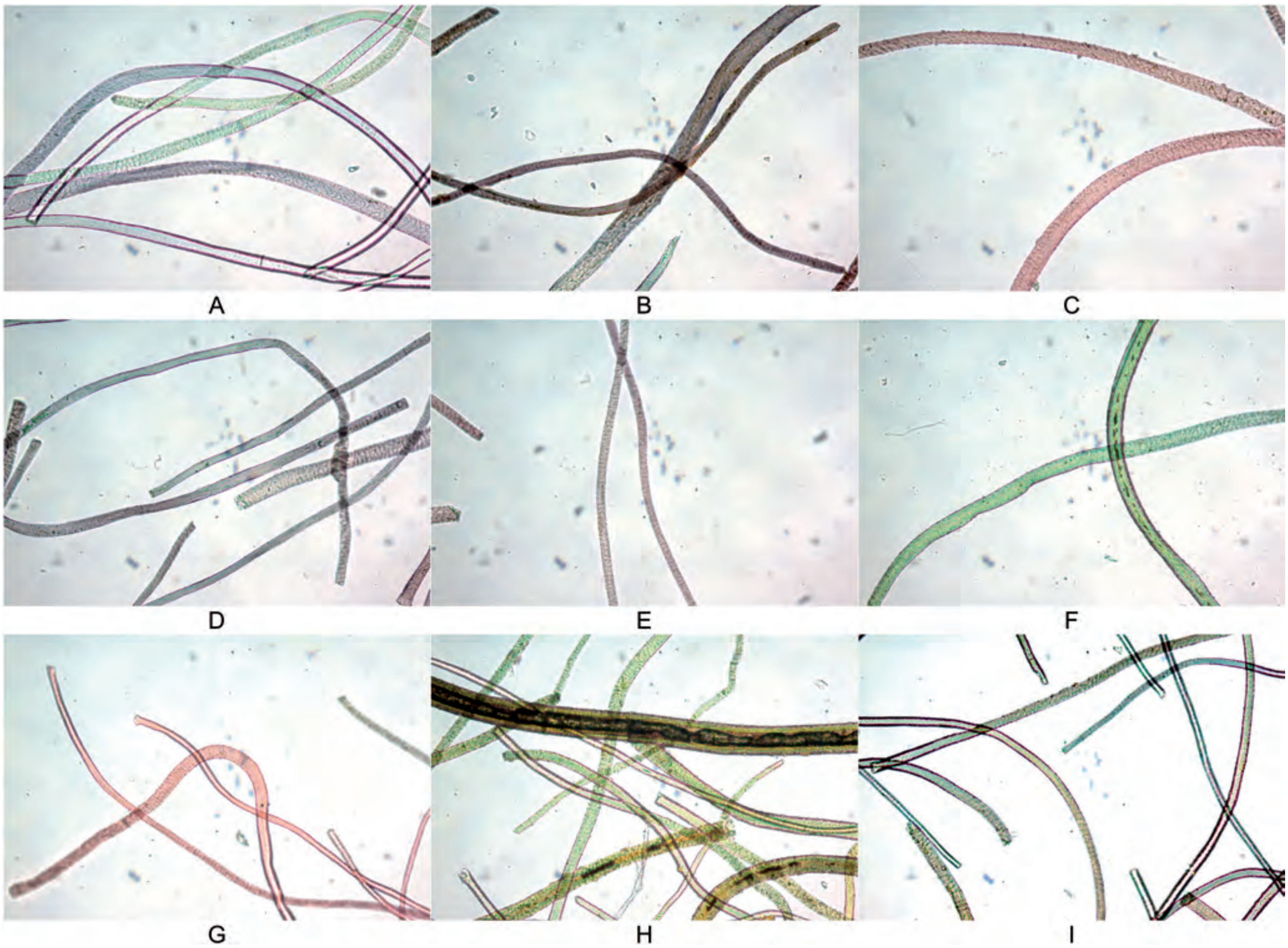


Fig. 4: Micrographs of fibres (100 x magnification). A) ÆIN 949 purple sample: The fibres appear uniform and with a clearly visible scale layer. Different nuances of blue, green and purple can be distinguished. The light green fibres are probably the undyed fibres observed in the dye analyses. B) ÆIN 950 blue sample: Different shades of blue and purple can be seen in the fibres. The fibre diameters appear slightly uneven. C) ÆIN 953 red sample: The fibres have slightly pink nuances. They have a visible scale layer and a round shape. The fibre diameters appear slightly uneven. D) ÆIN 954 blue sample: The fibres have bluish-purple nuances. They are uniform and have a clearly visible scale layer. E) ÆIN 955 red sample: The fibres appear slightly pink. They are uniform and have a visible scale layer. F) ÆIN 956 blue and red samples: The blue fibres appear greenish and with discontinuous medulla. The red fibres are uniform and in orange nuances. G) ÆIN 960 blue and red samples: The blue fibres have a visible scale layer and the fibres are damaged. The red fibres appear with pink and orange nuances. The fibre diameters vary. H) ÆIN 960bis blue sample: The fibres have green and yellowish-green nuances. The fibre diameters vary and continue as broken medullas are visible. I) ÆIN 1021 blue sample: The fibres have green and purple nuances (Images: Irene Skals)

documentation. All samples were identified as wool (table 1). This identification is evident from the often very visible scale structure and the roundish shape of the fibres (fig. 4).

Conclusion and future perspectives

Although the NCG collection is small the information that has been extracted from the technical and instrumental analyses is a valuable addition to the general knowledge about this particular group of textiles. The lack of archaeological methodology during their excavation has meant a great loss of information about the society which now has to be extruded by analyses of the preserved fragments.

A more exact dating of the textiles is of great interest since very few late antique textiles have an exact date. Furthermore, knowledge about the dye sources and dyeing practices is most helpful together with other material-based characteristics, such as the weaving technology and iconography, to further situate the individual finds in a broader historical context. To date, there is an agreed understanding of the most common dye sources in Egyptian textiles, but knowledge about the less common dye sources is based on only a few detections. This merits further study by widening the range of analysed textiles. This will improve and refine knowledge about the possible relationship between the use of a dye and a particular period or economic situation, which may eventually facilitate dye analyses as an indirect dating method as was recently the case with Indian lac (De Moor et al. 2017).

It would be highly relevant to compare the HPLC results with non-invasive techniques for detecting dyestuffs, particularly colour spectrometry. A study by Fuchs and Paetz gen. Schieck performed on 19 late Roman textiles from Egypt in the collections of the Deutsches Textilmuseum in Krefeld (Germany) has demonstrated how dyestuff s can be detected with colour spectrometry also known as VIS spectrometry. This non-invasive method records how a sample reflects incident light in the range of 380 nm to 730 nm (visible light). Computer software allows the spectrum to be plotted with its first derivation and the result is visualised in a diagram, which is compared to a reference database. The method is efficient in certain cases, but has its limitations: black and white are not detectable by the instrument, and yellow dyes cannot be distinguished on textiles. In addition, the identification of dye mixtures is another major challenge. The species of scale insects cannot be identified from the red shades. The study was able to detect the following dyestuffs: shellfish purple, cochineal, madder, indigo, and possibly safflower, sawwort, and weld (Fuchs & Paetz gen. Schieck 2011).

Further ways forward in the study of the textiles could be to include the identification of mordants through either examination with micro-invasive SEM-EDX, which is an accepted technique for such identifications, or through examinations with micro x-ray fluorescence spectroscopy (μXRF), which is a non-invasive technique suitable for the detection of inorganic compounds. Thus, Zvi Koren has recently suggested an XRF method for the identification of muricid purple based on the detection of bromine (Koren 2016). However, bromine has also been detected in the presence of lichen dyes, and thus, this method can only be used in combination with the detection of organic indigoid dye compounds to provide evidence for the presence of muricid purple (Aceto et al. 2015). Moreover, it is possible that XRF could be useful for the identification of iron-based mordants (Pozzi et al. 2012, 187). It should be noted, however, that there are certain limitations to this technique for the detection of light elements such as aluminium, which is important for the identification of textiles mordanted with alum. High-resolution x-ray images are a further non-destructive method to consider in the study of ancient textiles. Thus, a study of 39 Late Antique Egyptian textiles in the collections of the Museum of Montserrat, Barcelona (Spain), illustrated how x-ray images makes it possible to follow the weft and warp threads on a computer screen and gain data and insights into the ways of working the loom. Furthermore, the study showed how x-rays can illustrate, for example, the use of substances as consolidants in the fibres (Borrego & Vega 2015, 376-378). The same study included multispectral analyses involving images taken in the visible and near infrared ranges (FIR), and by ultraviolet fluorescence (UVF). This study showed that UVF photography can assist in differentiating linen from wool fibres if they are undyed (wool presented a bluish fluorescence, linen a pinkish one) as well as revealing stylistic details, which were no longer visible to the naked eye (Borrego & Vega 2015).

A further step could be to test the use of photoluminescence photography as a non-invasive method for the identification of red dyes. The efficiency of photographic techniques for detecting colourants in archaeological textiles (although not specifically Egyptian) was suggested by a study, employing ultraviolet and infrared photography (Baldia & Jakes 2007). The study showed that photographic techniques can determine the exact nature of the applied colourants on cellulosic or proteinaceous textiles, thus providing a means to select sampling sites of clearly different chemical compositions based on differences indicated in the respective images. Photoluminescence is a form of luminescence (emission of light) following photoexcitation (excitation by photons) of a shorter wavelength than that of the emission (see, for example, Dyer et al. 2013 for the use of multispectral imaging). A combination of UV-induced visible fluorescence (UVF) photography and visible-induced visible (Vis-Vis) luminescence photography could be interesting to test in relation to ancient textiles. UVF photography is widely used in the examination of artefacts to reveal the presence and spatial distribution of red, organic lakes which fluoresce in a characteristic coral-red (De la Rie 1982; Costello & Klausmeyer 2014; Grant 2000a; 2000b; Dyer et al. 2013). Vis-Vis luminescence, on the other hand, is a very recently published technique aimed at detecting and mapping organic, red lakes (Kakoulli et al. 2017). It could be of great interest if such photographic, non-invasive techniques could be employed as a preliminary indication of dyes, since this would allow a more targeted sampling strategy.

A similar non-invasive study has recently been carried out on the collection of ancient Egyptian textiles from the Museo Egizio in Torino (Italy). This collection was analysed with fibre optics UV-Vis diffuse reflectance spectrophotometry (FORS) and portable fibre optics fluorimetry (FL), which proved to be a very useful technique for the identification of dyes (Gulimini et al. 2016). Other authors have considered Late Antique Egyptian textiles as case studies for the comparison of UV-Vis, fluorescence, and mass-spectrometry detectors in HPLC detection of natural dyes (see, for example, Szostek et al. 2003).

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Patricia Hopewell and Susanna Harris

Blue dyed textiles in Early Iron Age Europe: Accessible or exclusive?

Abstract
Evidence for blue dyed textiles becomes widespread in Europe during the first millennium BCE. The dyestuff was likely dyer's woad - *Isatis tinctoria* L. While archaeologists have done much to understand the dyeing process, archaeobotany and chemical analysis of woad dye, there remains a question as to how accessible blue colour textiles were at this time. The aim of this research is to investigate the accessibility or exclusivity of woad dyed blue textiles in this period in terms of the resources, knowledge and skills required to produce them by asking the question "how many woad plants does it take to dye 1 kg of wool yarn blue?"

Keywords: Blue, dyeing, *Isatis tinctoria* L., woad, wool, textile, first millennium BCE, Iron Age, Mediterranean, experimental archaeology

Blue textiles and dyer's woad (*Isatis tinctoria*) 1000-500 BCE Europe

Blue dyed textiles are known from at least the second millennium BCE in Egypt and Europe although evidence becomes more frequent during the first millennium BCE (Wild & Walton Rogers 2003, 25-26; Cardon 2007, 374; Hofmann-De Keijzer et al. 2013, 143-145). One source of blue dye is natural indigo pigment, attained from the chemical synthesis of indigo precursors in leaves harvested from a range of different plant species, genera and families (Angelini et al. 2006, 285). In this paper, the terms "indigo precursors" or "indigotin" are used to discuss dye chemistry, and "indigo pigment" when focusing is on the dyestuff. The research and experiments reported here were only concerned with the woad plant (*Isatis tinctoria*). No products from tropical indigo (*Indigofera tinctoria)* were used as this plant is not relevant to the archaeological period and place in question.

Isatis family plants produce indigo precursors (indican, isatan B, and other isatans), which are extracted from the leaves and used to make indigo (Angelini et al. 2006, 286). Chemical analysis of dye in archaeological textiles detects the presence of indigotin. However, it cannot identify plant species (Angelini et al. 2012, 286). On the basis of its botanical presence in the region, *Isatis tinctoria* L is believed to be the source of an indigoid blue dye found in textiles in the first millennium BCE in Europe and the Mediterranean basin (Zohary et al. 2012, 167). Commonly known as dyer's woad, it belongs to the mustard family (*Brassicaceae*) (Hurry 1930, 1; Balfour-Paul 1998, 93; Zohary et al. 2012, 166-167). The geographical origin of *Isatis tinctoria* L. is debated; its native origin is usually attributed to Asia or southwest Asia, and areas of south/southeastern Europe (Zohary et al. 2012, 166; Guarino et al. 2000, 396).

Archaeological evidence of *Isatis sp.* seeds and accounts in classical literature demonstrate that woad, along with other plant dyes such as madder, was grown in the Mediterranean, temperate Europe and southwest Asia from the first millennium BCE (Körbe-Grohne 1987; Zohary et al. 2012, 166; Hofmann-de Keijzer et al. 2013, 143-145). Traces of indigotin are found in textiles across Europe from the late second, and more frequently from the mid-first millennium BCE. For example, indigotin is detected in a sizeable proportion of textiles from the Middle Bronze Age (1458-1245

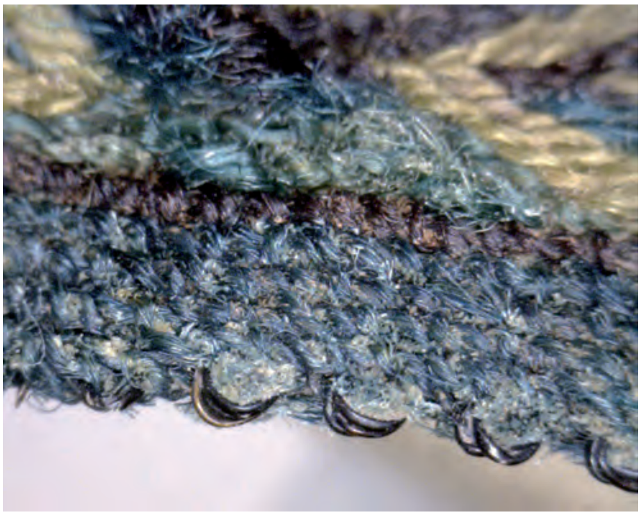


Fig. 1: Tablet woven band with several shades of blue yarn. Hallstatt Textile 123 (Image: Margarita Gleba, courtesy of Natural History Museum Vienna)

cal. BCE) and Early Iron Age deposits at the Hallstatt salt mines, Austria (Grömer et al. 2013, 451-452; Hofmann-de Keijzer et al. 2013, 142-143) (fig. 1). The borders of two garments from a well-furnished man's burial, Tomb 89, Lippi Necropolis in Verucchio, Italy, circa 725 BCE to 675 BCE were dyed with indigotin in combination with madder (*Rubia peregrine L.*) or tannins (Stauffer et al. 2002, 216; Stauffer 2012; 247-250). Wool stitching in clothing found at Riesenferner/ Vedretta di Ries, Italy, 795-499 cal. BCE has a blue colour, chemically identified as indigo pigment (Bazzanella et al. 2005). The elaborate princely burial of Eberdingen-Hochdorf, Germany, circa 540 BCE, has splendid coloured textiles, including those dyed blue and red (Walton Rogers 1999; Banck-Burgess 2014, 150). There are also blue textiles shown in pictorial representations. The colourful paintings inside the Etruscan tombs of Tarquinia, Italy, circa 550 BCE, depict men and women wearing vivid plain and patterned blue and green (potentially yellow/blue dye combination) textiles (Steingräber 1986) (fig. 2). While in archaic Greece, the robes and patterned borders of garments on marble statues of young women, possibly goddesses (circa 520 to 500 BCE), are painted with blue and green pigments, presumably representing blue or green textiles (Catalogue 2012, 32, 40).

There has been significant research on the colour of woad dyed textiles and the dye process (Hartl & Hofmann-de Keijzer, 2005; Hartl et al. 2015). However, in contrast to the attention given to the exclusivity of shellfish purple dye for textiles (Edmonds 2000; Ruscillo 2005; Landenius Enegren & Meo 2017), woad blue textiles of this period are rarely considered

Fig. 2: Blue and green clothing, Tomb of the Lioness, Tarquinia, Italy circa 550 BCE (Image: Susanna Harris, by kind permission of Polo Museale del Lazio – Tarquinia (VT), Necropoli di Monterozzi)

<table>
<tr><td colspan="3">Planting in early spring
↓
First leaf harvest in early to late summer
↓
Second & subsequent leaf harvests in autumn
↓
Prepare leaves in one of the following ways:
↓</td></tr>
<tr><td>1.Use fresh leaf</td><td>2. Pulp leaves, mould and dry to make into woad balls
↓
Crush, soak or macerate woad balls in preparation for the dye vat.</td><td>3. Cut, crush, macerate leaves in warm water, follow precipitation and aeration processed to make into woad powder (woad pigment)</td></tr>
<tr><td colspan="3">↓
Prepare dye solution
↓
Prepare vat
↓
Add dye solution to vat
↓
Dip fibres, yarns or textiles in vat
↓
Repeat dipping to desired shade or until vat is exhausted
↓
Refresh vat with new dye solution</td></tr>
</table>

Table 1: *Chaîne opératoire* of the main stages of growing and harvesting dyer's woad (*Isatis tinctoria* L.), three alternative forms of dye stuff preparation, vat preparation and dyeing

by archaeologists in terms of their accessibility or exclusivity. Yet, this is crucial for understanding the significance and value of blue textiles. Long distance connections and the competitive relationships of early urban living across the Mediterranean and central Europe in the mid-first millennium BCE created the desire for more, and more expensive possessions. The expense and exclusivity of fine, colourful textiles make them a ready form of personal comparison. They may be a means to justify and legitimise the dynamics of power (Harris 2017, 683). This raises the question: were certain colours more accessible than others?

Methodology

By posing the question "how many woad plants does it take to dye 1 kg of wool yarn blue?", this research aims to investigate the accessibility or exclusivity of woad dyed blue textiles by considering the resources, knowledge and skills required to produce them. This question was investigated through interviews with small-scale commercial dyers, published literature and experimental dye vats. The *chaîne opératoire* of woad dyed textiles (*Isatis tinctoria* L.) was analysed in order to investigate the accessibility of textiles dyed blue. This analysis considered the resources, knowledge and skills required at each stage of the process using three lines of evidence: literature on woad growing, processing and dyeing; interviews with small-scale commercial dyers (Brenac, Howard and Lambert) and one dyer working in a professional workshop (Roberts), all of whom were asked qualitative and quantitative questions about their experiences growing and dyeing with woad; and the use of experimental dye vats to investigate the quantity of woad plants required to dye a specified weight of wool yarn blue. The use of the vats permitted actualistic process and function experiments (as in Outram 2008, 2) using accurate materials (single spun wool yarns, dye ingredients) to test the hypothesis that is both quantitative (number of plants, weight of wool) and qualitative (knowledge and skills). It was recognised that other colours can be achieved with woad vats (Hartl 2015, 581, fig. 15) but the concern here was with achieving blue.

Evaluating the *chaîne opératoire* of woad dyed yarns

The main stages of the *chaîne opératoire* of woad growing, processing and dyeing are outlined in table 1.

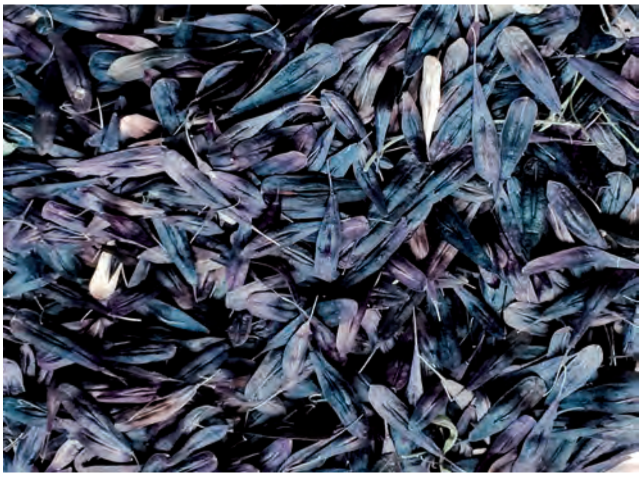


Fig. 3: Modern seeds of dyer's woad, *Isatis tinctoria* (Image: Patricia Hopewell)

From woad seed to plants

Historically, woad was grown across Europe in a variety of climates and terrains. Woad seeds should be sown in a rich, alkaline, well-drained soil for robust plant growth (fig. 3). The tendency of woad to leach the soil of all goodness led to it being a banned crop in some areas of 16th century England (Hurry 1930, 30). A biennial plant, the source of indigo pigment in *Isatis tinctoria* is present during the first year of growth when the leaves are at the rosette stage (Angelini et al. 012, 285), and a plant can be harvested multiple times. In southern Italy, woad plants were sown in levelled, furrowed ground in autumn (October) or early spring (February). The plants were weeded, hoed several times, and thinned if they had been planted too closely (Guarino 2000, 398). The first leaf harvest was in early June and repeated up to six times over the next two to three weeks, although the quality of the indigotin in the leaves decreased with subsequent harvests (Guarino et al. 2000, 398). Left to seed, dyer's woad produces ample seeds; in some places woad is an invasive weed. An individual woad plant can measure up to 120 cm in height, and 60 cm in diameter with as many as 90 leaves (Guraino et al. 2000, 395) (table 2). Today's cultivated varieties are typically smaller, and often harvested when they are 25 cm high and with a rosette diameter of around 30 cm (Angelini et al. 2012, 285-295). According to interviews with the growers, depending on a variety of growing factors, the leaf from a woad plant can weigh between 200 g to 700 g (Howard 2019 pers. comm.; Roberts 2018b). The quantity of leaves to one plant depends on many factors, including growing conditions and the health of the plant. A farm in Rochefort, France, cultivates 11,000 to 20,000 plants in one hectare of land (one hectare equals 10,000 m²). The plants measure 30 cm to 40 cm in diameter with 20 to 50 leaves on each plant, with a mean of 25 to 35 (Brenac 2016, pers. comm.). Here, plants are the smaller modern variety. In a good year, there are up to 50 leaves per plant for the first harvest and 30 to 40 leaves per plant for the second harvest. In a poor year, there are as few as 20 leaves per plant (Howard 2019, pers. comm.). However, the size of plant does not guarantee a higher indigotin content. A study of *Isatis tinctoria* cultivation showed that higher air temperatures and radiation coupled with low rainfall and regular irrigation led to a higher isatan B content, the precursor most important for indigo pigment production (Angelini et al. 2012, 289). This correlates well to growers' reports that higher temperatures produce plants with more indigotin content.

From woad plants to dye stuff

Fresh leaves can be used directly or processed through a complex chain of biological reactions that take place during the dyeing process (Cardon 2007, 338-340). In current day practice, dyers prepare the plant in one of three ways: fresh leaf, woad balls or woad powder (also referred to as woad pigment). It is not known which process was used in the first millennium BCE in Europe.

Fresh leaf

The woad leaves are picked from the plant, immersed in water with ingredients such as wood ash, soda ash (sodium carbonate, Na_2CO_3) and urine which create an alkaline liquid and commence fermentation (Balfour-Paul 2011, 102) (fig. 4). Urine was used historically in the dye process but the technique is not widely practiced today.

Woad balls

Woad balls are made by pulping fresh leaves, which are moulded into balls and dried (Cardon 2007, 369; Balfour-Paul 2011, 102) (fig. 5). Historically, leaves or woad pulp balls were left to ferment, a process called couching. In the 19th century, the woad balls were broken up and ground to a powder, whereupon it was sprinkled with water and allowed to ferment for about nine weeks, and turned regularly, with particular care taken regarding the temperature, which should not exceed 52°C (Hurry 1930, 26; Cardon 2007, 369). According to Howard, approximately 500 g of fresh leaf is required for one 60 g/70 g dry weight woad ball (Howard 2019, pers. comm). About seven to ten times the weight of fresh leaf is required to make a woad

Fig. 4: Fresh woad leaves tightly packed in a sealed vessel to ferment (Image: Patricia Hopewell)

ball; a ball equates to around one or two plants' worth of leaf depending on the size of the plant. Woad ball making is an historic practice, and today are only made by contemporary dyers out of interest and curiosity.

Woad powder

Woad powder is commonly referred to as woad pigment being the powdered preparation used today. There is insufficient evidence to suggest which process was used in prehistory. In the experiments, woad powder was used as this is most familiar to the dye experts involved. In present day commercial woad production, the fresh woad leaves are prepared as powder to maximise the indigo pigment yield (fig. 6). The leaves are steeped in hot water at 70 °C to 75 °C for seven to ten minutes to damage the wax surface of the leaves (Stoker et al. 1998, 317) and extract the precursors, indican and isatin B; this leads the production of indoxyl (Cardon 2007, 340-341). After removing the leaves, the water is rapidly cooled to prevent the loss of the indigotin. At 25 °C, calcium hydroxide is added providing the alkalinity required to neutralise the acids produced during fermentation,

Fig. 5: Two prepared woad balls (Image: Patricia Hopewell)

until the solution turns green and the pH is between 10.5 and 11.5. It is then aerated for approximately 20 minutes to precipitate the blue pigment. The mixture is settled overnight. After the surplus water is removed, solid citric acid is added, which releases the indigotin. The mixture should turn blue and the pH falls to between 4 and 5. The solution is again left overnight, any excess water is removed, and the remaining sediment is dried to a powder (Howard 2019, pers.comm.).

According to Howard, approximately 5,000 woad plants or 1 tonne (1,000 kg) of woad leaf is needed to make 500 g of woad powder (Howard 2019, pers. comm.). That equates to approximately five plants or 1,000 g (1 kg) of leaf to make 0.5 g woad powder (table 2). At Bleu de Lectoure, Gers, France, they use 1 tonne of leaf to make 2 kg of powder. This is similar to the 1.9 kg to 2.3 kg of woad powder obtained from 1 tonne of woad leaf referred to by Cardon (2007, 371). According to Brenac (see table 2, 2016, pers.comm.), 1 tonne of leaf produces 1 kg to 2 kg of woad powder. That equates to approximately 1 kg of leaf to produce

Fig. 6: Two woad powders of different strength purchased from The Woad Centre, Norfolk. Both batches of powder are prepared from dyer's woad, *Isatis tinctoria*, which is grown on the farm. Prepared woad powder is also called woad pigment (Image: Patricia Hopewell)

Plant size	Plant weight	Plants grown on 1 ha land	Fresh leaf weight: one woad ball	Number of woad plants to 1000 kg leaf	Weight of leaf: woad powder	Woad powder to dye wool fibre / yarn	Plant require d to dye 1 kg yarn	Geographical location	Source
H 120 cm, Diam. 60 cm	-	-	-	-	-	-	-	Southern Italy	Guarino et al 2000, 395
H 25 cm, Diam. 30 cm	-	-	-	-	-	-	-	Pisa, Italy	Angelini et al 2012, 287
-	700 g	-	-	-	1 kg leaf: 1 to 4 g	1 g dyes 20 g fibre light to mid blue*	-	Birmingham, UK	Teresinha Roberts 2018b, and pers.comm 2018a
-	200 g	-	500 g leaf : 60/70 g woad ball	5,000 plants	1,000 kg: 0.5 kg	-	-	Norfolk, UK	Ian Howard, The Woad Centre
Diam. 30-40 cm	-	11,000-20,000	-	-	1,000 kg: 1- 2 kg	-	250 - 1,000	Rochefort, France	Patrick Brenac, Couleurs de Plantes SAS
-	-	-	-	-	1,000 kg: 2 kg	-	-	Gers, France	Denise Lambert (Anon. *ca.*2016)
-	-	-	-	-	-	10-20 g dyes 200 g light to mid blue*	-	North Wales, Cambridgeshi re, UK	Experimental vats with Helen Melvin & Susanna Wareham

Table 2: Quantity of dyer's woad plants *Isatis tinctoria* L. required to produce dye ingredients based on interviews and published literature

1 g to 2 g of woad powder. For Roberts, 1 kg of woad leaf will produce between 1 g to 4 g of woad powder (Roberts 2018b). From these interviews, it is apparent that 1 kg of woad leaf can produce between 0.5 g and 4 g of woad powder, although for the commercial growers this range is more restricted with 1 kg of woad leaf producing between 0.5 g and 2 g of woad powder. In terms of the number of plants, based on weight of an individual plant between 200 g and 700 g, from 1.5 to 5 woad plants are needed to make 0.5 g to 2 g woad powder.

Dyestuff to blue textiles

The purpose of the experimental dye vats was to recreate the process of dyeing wool yarn with woad to gain quantitative and qualitative results and evaluate the knowledge, skills and resources required to dye textiles blue. The experiments were carried out with experienced dyers Helen Melvin in north Wales and Susanna Wareham in Cambridgeshire, United Kingdom. Dye vats were prepared using three sources of woad: fresh woad leaf, woad balls, and woad powder. Fresh leaves were used from plants grown from seed in Melvin and Wareham's gardens. All woad powder and woad balls were sourced from Ian Howard at The Woad Centre, Norfolk, United Kingdom. All vats were prepared in different parts of the United Kingdom in July with temperatures of approximately 20˚C in north Wales and 25˚C in Cambridgeshire. Woad is insoluble in water; to prepare a fermentation vat today, woad is often chemically reduced to a water soluble form known as leuco-indigo (Hurry 1930, 35; Cardon 2007, 367-377). A reducing agent removes the oxygen from the vat; with the oxygen removed, the indigotin becomes soluble in water. A fermentation process must take place by adding an appropriate substance. Contemporary practitioners use various agents, such as natural sugars from fruit (very ripe pears, bananas, dates, fructose) or wheat bran, medicinal plants or other dye plants (for example, madder, as used in the vats below). To assist in this process, lime (calcium hydroxide, $Ca(OH)_2$) is added as a base for the purpose of controlling alkalinity. Fresh or dry chopped madder roots may be used. However, a larger quantity of fresh madder would be required per weight of fibre. At this point, it becomes an alkaline soluble substance of pH 9/10, commonly called indigo white. Today, woad is manufactured using reducing agents such as sodium

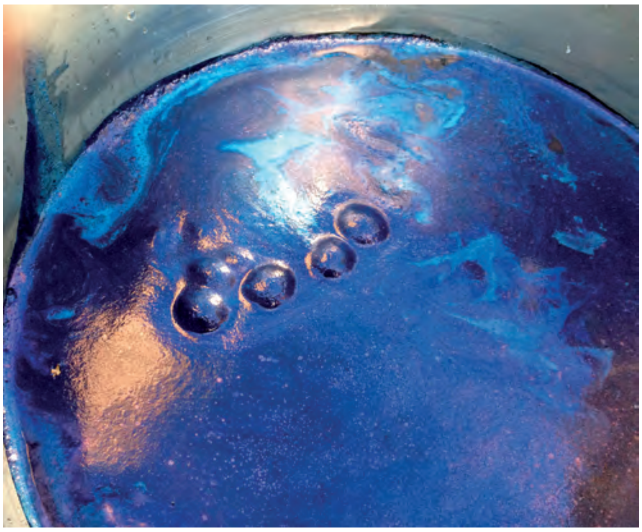


Fig. 7: The woad dye vat (Image: Patricia Hopewell)

hydrosulphite or thiourea dioxide which are added to remove the oxygen from the vat; these chemicals were avoided in the experimental vats.

Single spun, non-pigmented wool yarn was selected from Shetland breed sheep. The yarn was scoured before dyeing to enable the dye to penetrate evenly. Scouring removes the natural lanolin from the sheep by soaking the yarns in a soap solution for several hours then rinsing it well. The quantity of woad and wool were measured for each vat. For the sake of consistency, the aim was to dye the wool mid-blue, Pantone 2915 UP (PANTONE® 2018). This is based on preserved blue dyed yarns from textile fragments from Vedrette di Ries, Italy and Hallstatt, Austria and blue colour cloth and clothing in the Etruscan tomb paintings of Tarquinia (for example, fig. 2). It was important to gauge the shade to a certain degree, as it requires more dye (stronger dye vat and/or multiple dips) to dye a cloth dark blue than light or mid-blue. As all dyers know, it is not possible to precisely control the shade of each dye vat. However, the gradation of blue that can be obtained from a dye vat is well known (Cardon 2007, 58); dyers can judge the depth of colour a vat will dye, and learn to adjust the number of dips or strength of the dye vat to achieve the desired shade (fig. 7 and 8).

In all cases, 200 g of wool yarn was dipped to achieve the target mid-blue colour. The results were recorded up to that point. Beyond that, further yarn could have been dyed but the shade may have changed, and weakened as the vat reached exhaustion. The vat details are documented in table 3.

The experimental vats were not fully successful. Despite working with experienced woad dyers, the dye vats using fresh leaf or woad balls failed. This led to the use of woad powder (*Isatis tinctoria*) produced from woad plants grown at The Woad Centre in Norfolk, United Kindom, a substance with which today's dyers are more familiar.

Vats with fresh leaf

Fresh leaves were picked directly from the plant, tightly packed in glass jars with rubber seals and metal sprung clips to secure the lids, and left to ferment for 21 hours following a published recipe (Wicken 1983). Two of the fresh leaf vats followed a dye process using either wood ash lye and wheat bran or calcium hydroxide (lime) (table 3, Vats 1 and 2). The resulting beige or faint blue did not match the desired shade of mid-blue. The third fresh leaf vat contained human urine, pH unknown, which had been kept under warm conditions for eight weeks, as a fermentation aid. However, no blue colour was achieved (table 3 Vat 3). The poor colour results from the vats using direct dyeing with fresh leaves give credence to the necessity of long natural fermentation processes, which were used in the 16th and 19th centuries, for which the leaves were cut, crushed and subsequently went through a fermentation over several weeks (Hurry 1930, 26). Dyeing with fresh leaf and urine proved challenging, despite being carried out with experienced dyers. Melvin in North Wales had many earlier successes dyeing with urine; in this instance, with a later addition of dates, a blue colour was achieved (table 3, Vat 7). Reasons for the failure of the urine vats could have been insufficient warm weather,

Fig. 8: Wool yarn drying after dyeing different shades of blue (Image: Patricia Hopewell)

insufficient time allowed for the fermentation process, or poor indigotin content in the leaves. Hartl and team also reported a disappointing outcome using urine in north Wales. The process took so long that her urine experiments were discontinued (Hartl et al. 2015, 35). Despite efforts made to maintain optimum conditions, the results with urine were disappointing, as it is considered to be a relatively easy process.

On reflection, given the reports from the commercial growers that it takes 1 kg of woad leaf to produce 0.5 g to 2 g of woad powder, the pale turquoise achieved with the fresh leaf vats was probably due to the low weight of fresh woad leaf (83 g to 300 g) used in these vats, and the resulting weak dye solution rather than a failure of the vat. For this reason, the fresh leaf vats did not provide quantitative results for the calculations.

Vat with woad balls

To prepare the dyebath, the woad balls were crushed, sprinkled with water and left for an hour or so then added to the vat. The crushed balls were left in the vat for the whole dyeing process. Following current dye practices, the process of couching was not followed here, which may be one of the reasons the initial results failed to achieve a blue colour; blue was achieved with the addition of further lime and ripe fruit (table 3, Vat 4). As with the vats using fresh leaves, the vats with woad balls did not result in mid-blue dyed yarn, only light blue. Hence, as with the fresh leaf vats, the woad ball vat did not provide quantitative results for calculations. Similarly, the results from the interviews were not sufficiently clear as to the quantitative results of woad balls to dye outcome.

Vats with woad powder

In two woad powder vats, ripe fruit (pH unknown) was added to aid fermentation. Vats with apples failed as the acid content was too high. Pears and prunes produced good results (table 3, Vats 5 & 6). Vats using woad powder and ripe fruit as a fermentation aid produced suitable blue yarns. Doubling the quantity of woad powder in Vat 6 resulted in darker shades of blue than Vat 5.

As with the fresh leaf with urine (table 3, Vat 3), the woad powder vat with urine as a fermentation aid produced a dull beige colour, improving with the addition of ripe fruit to light blue (table 3, Vat 7). Three woad powder dye vats were undertaken using dyer's madder *(Rubia tinctorum)*, as an aid to fermentation, (table 3, Vats 8, 9, 10). Contrary to expectation, this recipe produced blue dyed textiles, not purple, despite the large ratio of 90 g of madder to 30 g of woad powder.

Lime was added to the vat to control the alkalinity and madder roots were used to aid the fermentation process in the dye vat. It is aerobic bacteria which remove the oxygen allowing the indigo to dissolve. In the dye vat, the madder's role is to help anaerobic bacteria convert the insoluble indigo into indigo white. In the past, aged urine was used extensively as a source of alkali, which is necessary for the reduced indigo (indigo white) to dissolve. The alkali and madder do not help to remove oxygen (John 2016, pers. corresp.). Madder is a versatile plant for dyeing and to aid fermentation and is important for today's natural dyers. Charllotte Kwon at Maiwa Handicrafts often uses madder for its fermentation properties when dyeing reds in organic woad vats (Kwon 2016, pers. comm.). The woad powder vat with ripe pears dyed a mid-blue colour, as did the vats with woad powder, madder and lime.

The vats using woad powder, with either wood ash lye and wheat bran or lime and madder were consistently successful, producing blue yarns. In terms of quantitative results, Vat 5 (table 3) used 10 g of woad powder to dye 200 g of wool light blue; Vat 6 used 20 g of woad powder to dye the same weight of wool yarn a mid to dark shade of blue. Those vats using 30 g of woad powder were not exhausted or dyed to a deeper shade of blue than required. According to Roberts, 1 g of woad powder will dye about 20 g of fibre (Roberts 2018b). This matches a general guide for contemporary dyers that 10 g to 20 g woad powder dyes 200 g of wool (Roberts 2016; Plantes de Couleur 2016).

How many woad plants are required to dye 1 kg of wool yarn blue?

Using the information gathered above, it is possible to attempt to answer the question: how many woad plants are required to dye 1 kg of wool yarn blue? In answering this question, there are three important variables to consider: the size of the woad plants, the quantity of woad powder produced from fresh leaves, and the potency of the dye. In addition, the resources, skills and knowledge required to achieve blue textiles are also considered.

Given the variability in the production processes, four possible scenarios based on the most and least productive results, excluding dye vats that failed (table 4) were assessed. Taking into consideration the results above from the commercial woad growers (summarised in table 2), it typically requires 1,000 kg of woad leaf to make between 0.5 g and 2 kg of woad power. Given a successful dye vat, this is enough to dye between 5 kg and 40 kg wool yarn mid-blue aiming for Pantone 2915 UP. From these results, and assuming that all stages of the process are at their

Vat & Practitioners	Ingredients	Dye process	Dips	Dye result on wool
1. Vats with fresh leaf (Melvin/Hopewell)	300 g Fresh woad leaf 1000 ml Wood ash lye 30 g Wheat bran	Pick leaves at first harvest – July/August Crush leaves, macerate in 1000 ml water at 50- 60°C, add wood ash lye (Wood ash is prepared by pouring boiling water over ashes in a bucket, leave to soak for several weeks, skim off the clear lye and discard the sediment). Heat until simmering, allow to rest, vat is now ready for dyeing. Vat maintained at pH 9 - 9.5	1st dip – no colour 2nd dip – 24hrs pale turquoise	
2. Vats with fresh leaf (Melvin/Hopewell)	83 g Fresh woad leaf Lime (calcium hydroxide, $Ca(OH)_2$)	Direct dye. Tear leaves into small pieces, fill 2000 ml jar with leaves, fill to the brim with boiling water, wait for bubbles to appear. Wait 30-40mins, strain off liquid and add 15 ml lime (calcium hydroxide)	1st dip - 2h 2nd dip – 4h	
3. Vats with fresh leaf (Wareham/Hopewell)	200 g Fresh woad leaf 1000 ml Urine aged 8 weeks, pH not known. 10/12 g Soda ash (sodium carbonate, Na_2CO_3) 2 Prunes	Pick leaves at first harvest – July/August crush leaves, macerate in 1000 ml hot water add leaf extract to urine, add soda ash. Add 2 chopped prunes. Daytime temperature maintained at 40° - 50°	After long dip – no colour	
4. Vats with woad balls (Wareham/Hopewell)	2 Woad balls 15 g Soda ash 5/10 g Lime (calcium hydroxide $Ca(OH)_2$) 3 Prunes	Woad balls were crushed initially with a wooden mallet, then rubbed between finger and thumb until fine, add approx. 400 ml cold water to moisten, add 2000 ml water, the local water in Cambridge is hard, at 30°, leave for 1 hour. Add soda ash and 5 g lime, wait 15 mins	1st dip pale yellow beige – 20 mins Add more lime (5g) Add 3 chopped prunes 2nd dip -30mins	
5. Vats with woad powder (Hopewell)	10 g Woad powder 2/3 Ripe pears 15 g Lime (calcium hydroxide $Ca(OH)_2$)	Filter the juice from crushed, boiled fruits by pouring gently through a sieve, (mesh size 6 x 6 mm) put in dye vat at 50°C Put the fruit in a cotton bag and put into the vat, add hydrated woad powder, lime, stir gently several times. When a bronze film occurs with bubbles on top the vat is ready. pH 9-9.5. With the exception of 1st dip, varying shades of pale turquoise	1st dip – 10mins 2nd dip – 30mins 3rd dip – 1hr 10mins 4th dip – 2hr 10	

Table 3: Dye vats using fresh woad leaf, woad balls and woad powder with details of ingredients, process, dipping times and colour outcome on 200 g single spun Shetland wool yarns

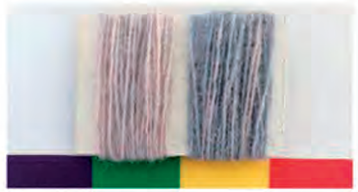
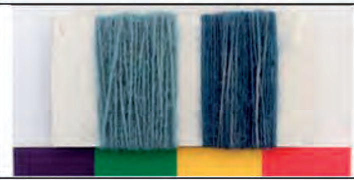
Vat & Practitioners	Ingredients	Dye process	Dips	Dye result on wool
6. Vats with woad powder (Hopewell)	20 g Woad powder 2/3 Ripe pears 15 g Lime (calcium hydroxide $Ca(OH)_2$)	Filter the juice from boiled, crushed fruits, by pouring gently through a sieve (mesh size 6 x 6 mm) add to water in dye vat 50°. Put the remaining fruit into a cotton bag and into the vat, add hydrated woad powder, lime, stir gently several times. When a bronze film occurs with bubbles on top the vat is ready. pH 9-9.5 Increased amount of woad powder resulted in shades ranging from turquoise to dark blue, very satisfactory result.	1st dip – 5mins 2nd dip – 10mins 3rd dip – 15mins 4th dip – 20mins	
7. Vats with woad powder (Melvin/Hopewell)	20 g Woad powder 6000 ml Urine aged for 8 weeks 3 Dates	Add woad powder to warm water and mix well, add to urine, allow to mature for 6 days, pH9, maintain warm conditions at 40°- 50°	1st dip – 2hrs with the addition of chopped dates 2nd dip – 3hrs	
8. Vats with woad powder (Melvin/Hopewell)	35 g Woad powder 60 g Madder, chopped roots 500 ml Wood ash lye 20 g Wheat bran	Add woad powder to 50- 60 °C water and mix well. Put water, madder, bran, and wood ash lye in a pan and boil until a scum appears and the top turns from pink to purple. Cool to 40°, add woad solution. Maintain temperature. Leave until bubbles form on top. pH 9 - 9.5	1st dip – 30mins with the addition of 5 chopped dates 2nd dip – 1hr	
9. Vats with woad powder (Wareham/Hopewell)	30g Woad powder 90g Madder powder 60g Lime (calcium hydroxide $Ca(OH)_2$)	Add madder to cold water, stir heat to boiling, sieve. Put woad powder in plastic jar with pebbles and hot water and shake well to hydrate, add to madder and stir. Sprinkle lime on top, stir gently and leave until liquid is a clear yellow green and bubbles form on top. pH 9-9.5	1st dip – 10mins 2nd dip - 15mins 3rd dip – 20mins 4th dip – 25mins	
10. Vats with woad powder (Hopewell)	10 g Woad powder 30 g Madder powder 20 g Lime (calcium hydroxide $Ca(OH)_2$)	Add madder to cold water, stir heat to boiling, strain through a sieve, (mesh size 6 x 6 mm). Put woad powder in plastic jar with pebbles and hot water and shake well to hydrate, add to madder and stir. Sprinkle lime on top, stir gently and leave until liquid is a clear yellow green. pH 9 - 9.5	1st dip – 5mins 2nd dip – 10mins	

Table 3 (continued): Dye vats using fresh woad leaf, woad balls and woad powder with details of ingredients, process, dipping times and colour outcome on 200 g single spun Shetland wool yarns

Quantity woad leaf	Quantity woad powder	Dye potency	Wool yarn dyed blue with 1000 kg leaf	Ingredients to dye 1 kg wool yarn blue
1,430 large woad plants produce 1,000 kg fresh leaf	to make 2 kg woad powder.	If 50 g powder is enough to dye 1 kg wool yarn	then 1,430 large plants produce 1,000 kg woad leaf makes 2 kg woad powder and dyes 40 kg wool yarn blue.	This means to dye 1 kg wool yarn blue requires 50 g woad power from 25 kg woad leaf of 35.75 large plants.
	to make 0.5 kg woad powder.	If 100 g powder is enough to dye 1 kg wool yarn	then 1,430 large plants produce 1,000 kg woad leaf makes 0.5kg woad powder and dyes 5 kg wool yarn blue.	This means to dye 1 kg wool yarn blue requires 100 g woad powder from 200 kg fresh leaf of 286 woad large plants.
5,000 small woad plants produce 1,000 kg fresh leaf	to 2 kg woad powder.	If 50 g powder is enough to dye 1 kg wool yarn	then 5,000 small plants produce 1,000 kg woad leaf to make 2kg woad powder and dyes 40 kg wool yarn blue.	This means to dye 1 kg wool yarn blue requires 50 g woad powder from 25 kg woad leaf from 125 small woad plants.
	to 0.5 kg woad powder.	If 100 g powder is enough to dye 1 kg wool yarn	then 5,000 small plants produce 1,000 kg woad leaf makes 0.5 kg powder and dyes 5 kg wool yarn blue.	This means to dye 1 kg wool yarn blue requires 100 g woad powder from 200 kg fresh leaf of 1,000 small woad plants.

Table 4: Four possible scenarios for the number of woad plants required to dye 1 kg wool yarn blue based on the data gathered in this paper. Three variables are considered: 1) size of the woad plant, 2) quantity of woad powder produced from fresh leaf, 3) potency of the dye

most productive, it could take as few as 36 large or 125 small woad plants with a yield of 25 kg of fresh woad leaf to produce 50 g of woad powder, which could be enough to dye 1 kg of wool yarn mid-blue. At a less productive level, it could take as many as 286 large or 1,000 small plants with a yield of 200 kg of fresh woad leaf to produce 100 g woad powder to dye 1 kg wool yarn mid-blue (see an overview of results in fig. 9).

What is noteworthy in these results is the wide range of plant numbers required to dye yarns blue: a dyer could require as few as 36 large woad plants to dye 1 kg wool yarn blue, or as many as 1,000 small plants. There are many factors that underlie this variation, which may originate at any stage of the process; much depends on the skill of the dyer.

Woad blue textiles: accessible or exclusive?

Dyer's woad likes a rich, alkaline, soil, well drained for robust plant growth. To gain a plant rich in indigotin, the growing variables are considerable; they include the prevailing conditions at planting through to harvesting, the climate, the latitude, length of daylight and ultraviolet rays, the length of hot dry days prior to processing (Howard 2019, pers. corresp.). A cool summer can have such an adverse effect that there is only one annual harvest, with devastating results. In a good year, woad plants grow easily and have a high indigotin yield; in a poor year, the opposite is true. This raises the question as to whether dyer's woad was widely cultivated across the Mediterranean in the Early Iron Age. The agricultural economy of this period was likely in small fields close to settlements, some of which must have been dedicated to dyer's woad with the intent to obtain blue dyestuff. In addition, farmers of the first millennium BCE would have needed to resolve a depletion in soil fertility after growing woad. The risks and rewards of farming were no doubt an aspect of life in the agricultural communities of the early first millennium BCE. Assuming the availability of the raw materials (seed, soil, climate), agricultural knowledge and skills, this blue dye source could be regarded as accessible, yet unreliably so.

What was learnt from the experimental dye vats? The complexity in processing woad plants into dyestuff, and the chemistry of the woad dye vat, adds elements of risk to the dyeing process. There are three distinct dyeing techniques: direct dyeing, mordant dyeing and vat dyeing. Direct dyeing involves boiling or soaking suitable plants in water, creating a dye bath into which the material to be dyed is immersed (Cardon 2007, 4). Mordant dyeing requires an agent to bind the dye onto the fibre, such agents include alum (aluminium sulphate), iron and tannin. Vat dyeing, as required for woad and shellfish purple, is a more complex affair because the dyestuff is insoluble and must be reduced to its soluble form in alkaline conditions to be absorbed by the fibres (Cardon 2007, 4-5). Vat dyeing requires greater knowledge and skills than direct dyeing or mordant dyeing. This hints at the possibility of specialist and secret knowledge. Despite

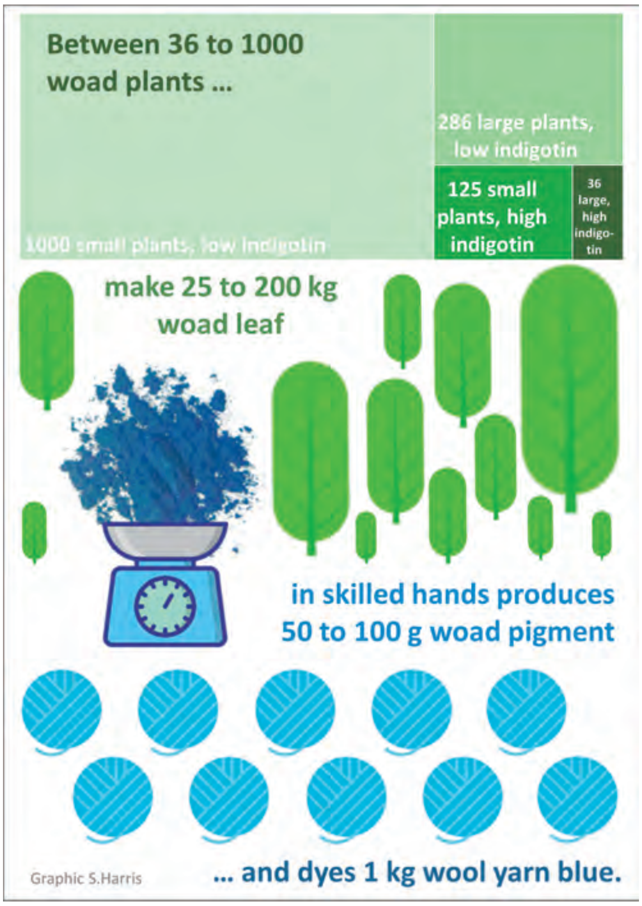


Fig. 9: Summary of results: how many woad plants does it take to dye 1 kg wool yarn blue? (Image: © Susanna Harris)

working with experienced dyers, the direct dyeing and urine dyeing in this experiment did not succeed. Woad dyeing is not predictable; there is always the possibility of shade differences or vat failure (see Hartl et al. 2015, 22-26). Encouragingly, once the dye vat is up and running, multiple dips or a richer dye solution (more dyestuff) can achieve a deep blue colour, until the vat is exhausted. It is well documented throughout history that woad dyeing is erratic. Repeating the same recipe under the same conditions will not guarantee success or the same shade of blue. Indeed, the historical and anthropological literature attests to the many mysteries surrounding indigotin extraction from a range of plants worldwide, and the resultant dye vats (Balfour-Paul 2011, 100, 119). In this way, the knowledge and resources needed to set up a woad dye vat and the skills and practices required to achieve blue textiles are less accessible than other dyeing methods, and the colour results are unpredictable. Thus, the skills to achieve blue dyed textiles may have been relatively exclusive.

At the beginning of this research, it was tempting to interpret the blue dyed textiles of the early first millennium BCE as relatively accessible. In suitable environments, the plant grows like a weed, and many contemporary home dyers report success dyeing with woad. During the progress of the research, it became apparent that these expectations are deceptive. Assuming the seeds became widely available across Europe in the first millennium BCE, dyer's woad was likely a relatively accessible raw material compared to shellfish purple. However, the unpredictability of the indigotin content in the plant, leading to the highly variable quantity of plants required to achieve blue textiles, plus the depletion of soils, makes this a somewhat unreliable crop. In addition, the specialist skills and intensive labour required in processing the plant into dyestuff, add to the unreliability of the dye vat in the hands of the inexperienced. It seems dyers today rarely report unsuccessful dye vats, giving a false sense of success. Indeed, two of the failed dye vats in this experiment are not reported here. Dye vats may, and do, fail in the sense that they do not result in blue dyed yarns (fibres or textiles). On the other hand, a successful dye vat is an asset to a dyer, who can prolong its life for months at a time, and use their skill to achieve a whole host of blue shades.

Dyers of the first millennium BCE skilled in the processes and knowledgeable about the techniques should expect repeated success, and with it the ability to produce various shades of blue, or indeed other colours. These all point to woad blue as a colour that was accessible to those with sufficient resources to counter the cumulative risks involved in obtaining it and the skills to carry out all stages of the process. Through this research it became apparent that woad blue dyed textiles were somewhat exclusive in terms of the plant resources and the complex skills required in processing the dye and creating a successful dye vat. A stripe or pattern of blue may have been an everyday luxury, to use the words of Lyn Foxhall (Foxhall 2005, 240), and available to many. By contrast, large dyed blue or indeed green (yellow/blue dye combination) textiles of the first millennium BCE may have been items of distinction. If this conclusion is correct, large quantities of blue or green textiles were part of the material culture of luxury, expense and exclusivity that characterised the life of early urbanites, aspiring elites, and wealthy communities of this period.

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The Textiles of Üzüür Gyalan: Towards the identification of a nomadic weaving tradition in the Mongolian Altai

Abstract

This paper presents the analysis of textiles from the tenth century Mongolian rock burial of Üzüür Gyalan. It is the only undisturbed rock burial discovered to date and presents a unique opportunity to examine a complete set of grave goods, both organic and inorganic, included in a Medieval horse-accompanied burial. The high degree of preservation and the prevalence of woven wool textiles set it apart from other rock burials where silk, sheepskin, and felt garments have been found. Certain features of the assemblage, including the abundance of the woven wools, their technical consistency, and evidence for household rather than specialised production, suggest the work of local weavers. Drawing comparisons with a living nomadic weaving tradition in Ladakh, Tibet, this paper relates aspects of the assemblage to production in a mobile pastoralist context.

Keywords: Mobile pastoralism, Mongolia, rock burials, Medieval Eurasia, household craft production

Introduction

Mongolian rock or cave burials (hadnii orshyylga) represent a long-running mortuary tradition attested from the third to the 17th centuries CE in which individuals were laid to rest in natural mountain crevices. The rock burials that have survived are typically found at high elevations in niches deep enough to provide shelter from the elements. To date, more than 100 rock burials have been recorded in Mongolia, of which relatively few have been comprehensively analysed. This is due in large part to the constraints of recovery excavation and the expense involved in conserving organic objects and mummified human remains, which are typical rather than exceptional in these contexts. Notable publications gathering together evidence of multiple rock burials include the German and Mongolian language catalogues of special exhibitions held in Bonn, Germany (Bemmann 2012) and Ulaanbaatar, Mongolia (Төрбат & Эрдэнэбат 2014).

Rock burials are almost always discovered accidentally by the herders who pasture their animals and camp on the slopes below them. Their stories echo the circumstances in which ancient and medieval herders

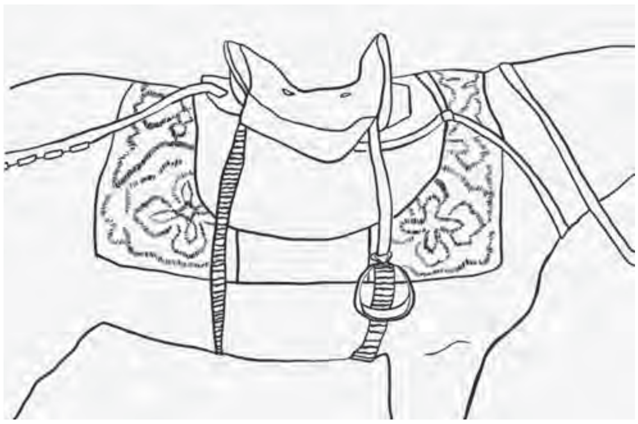

Fig. 1: Reconstruction of the tack, including saddle, embroidered saddle blanket, felt saddle pad, and girth as they may have appeared on the Üzüür Gyalan horse, based on the exhibition model constructed by the National Center for Cultural Heritage. The saddle is made from carefully fitted wooden components held together with rawhide thongs and covered with three layers of quilted felt. The heavy polish on the cantle of the saddle attests to its use over a long period of time. (Image: Kristen Pearson)

Fig. 2: Embroidered saddle blanket (detail). The embroidered designs that peek out from underneath the saddle at the front and back (fig. 1) are stitched on two separate panels of brown tabby fabric. One of the panels reveals a lack of forethought on the part of the craftsperson – the foliate shapes become distorted as they approach the cut edge of the fabric, showing that the embroidery was done after the fabric had been cut for the saddle blanket, that it was done freehand, and that the embroiderer miscalculated the space available. The designs on either panel match in terms of their motif but they vary in its execution. This may represent the work of two different people collaborating to produce a single object. (Image: Kristen Pearson)

may have interacted with the mountain landscape. In 2010, a group of herders on Mönkhkhairkhan mountain came upon a rock burial site when they had climbed up to the ridge to collect *baragshun*, a medicinal tar-like substance that seeps from the rocks in the ranges of Central Asia. The burial remained a secret until five years later, when two herders, D. Munkhtsooj and Ch. Alagaa reported the find to the local museum. The following April, a team from Khovd State University, along with members of the Mönkhairkhan Soum Cultural Center, went to investigate.

It was the unlooted grave of a middle-aged woman. She had been buried with a horse for riding and more than 40 artefacts, most of them organic (fig. 1 and fig. 2). The woman's body and that of her horse were naturally mummified, partially preserving their skin and hair. The site was named for a nearby spring camp, known locally as Üzüür Gyalan (bright corner), but a striking pair of embroidered boots quickly inspired a nickname: the "Adidas Boots" burial (fig. 3). The assemblage represents one of the largest collections of complete garments and textile objects ever found in Mongolia. This article presents a description of the Üzüür Gyalan textiles, particularly the woven wool fabrics, and evaluates their significance in the context of current understandings of textile production and consumption among ancient and medieval nomads.

Fig. 3: The "Adidas Boots" (photo/line drawing composite). Though the person who made these boots took care to conceal signs of reuse, all the decorative elements (the embroidered uppers and the straps with metal plaques) have been borrowed from other objects (see Pearson 2018) (Image: Kristen Pearson)

Fig. 4: Red *deel* (photo/line drawing composite). The Üzüür Gyalan woman was buried wearing her red deel, which stands out from the others not only because of its vibrant dyed colour, but also because of the polychrome silk applied to the collar, armpit gussets, and body (Image: Kristen Pearson)

Fig. 5: Tan *deel* (photo/line drawing composite). This *deel* is lined with skins, whereas the other two fabric *deel* are lined with felt. The gusset on the inner flap incorporates a small triangle of red fabric and a segment of more finely woven tan fabric, which would have been hidden when the *deel* was worn (Image: Kristen Pearson)

Overview of the burial

An initial description of Üzüür Gyalan was published in a report shortly after it was excavated in 2016 (Мөнхбаяр et al. 2016) The woman was buried wearing a red wool *deel* (fig. 4), brown and tan wool trousers, and leather and felt boots with embroidered uppers – the "Adidas Boots" (fig. 3). Tucked inside the boots were a samite fragment ripped into three pieces and a small white felt bag containing a horn comb and the broken corner of a mirror. The woman wore a headdress of silk, with an ornamental strip of leather appliqué over the brow. Her face was covered with a piece of yellow silk, over which was tied a purple silk eye mask. She was wrapped in two large felt shrouds, one of which was decorated with painterly designs in red and blue wool applied in the initial stages of the felting process – a pressed felt technique still used to this day in Central Asia (Bunn 2010).

Close to her body inside the shroud were a steel knife in a wooden sheath and a leather pouch containing two steel sewing needles. A small felt and leather bag was also placed near the body. This was packed with coils of plied wool and sinew thread, scraps of felt and leather, rovings of combed wool ready for spinning, a tassel of red-dyed horsehair. The woman's sewing kit evokes her work left unfinished when she died.

In addition to the garments she was wearing, the woman of Üzüür Gyalan was buried with additional sets of clothing: two pairs of wool trousers (fig. 7 and fig. 8), two wool *deel* (fig. 5 and fig. 6), an animal hide *deel*, a pair of plain leather boots with felt boot liners, a felt, fur and cotton hat, and a wool and silk hat. Small fragments of two poorly preserved garments were also found: one, lined with lambskin, may have been a third hat; the other is the sleeve of what may have been another *deel*. All of the clothing shows signs of wear and repair.

Other textiles included two wool saddle bags and one of felt, a soft, rectangular wool textile with pile loops (fig. 10 and fig. 11), two wool saddle blankets – one of which was embroidered (fig. 1 and fig. 2) – and a felt saddle pad. Two ovicaprid sacra were placed in the abovementioned felt bag, and additional ovicaprid elements, the remnants of a meal, were found inside the niche. Additional grave goods included two wooden trays, a wooden cup, a ceramic vessel encased in felt, a small iron cauldron, a large bag made from a case-skinned hide, a wooden rod, leather braided cords, and a forked tool made of wood. The woman was accompanied by a sacrificed horse with bridle, saddle, girths, and crupper, as well as the pelt—with head and legs attached—of a sheep. Both the horse and sheep had earmarks, an ancient form of animal identification still used on cattle and horses in Mongolia today. Zooarchaeological analysis has revealed biographical details of the horse, a chestnut gelding that – at 15 years of age when it was sacrificed – must have been a favoured riding animal (Onar et al. 2019).

A year after its discovery, the Üzüür Gyalan burial was featured in an exhibition at the Mongolian

National Museum along with an earlier male burial found in the same region. The objects were cleaned, conserved and photographed at the National Center for Cultural Heritage (Соёлын Өвийн Үндэсний Төв) under the direction of Ch. Enkhbat, and a Mongolian-language publication was prepared describing the burial, the finds, and the restoration process (Баярсайхан & Энхбат 2017). Radiocarbon C-14 analysis was conducted on nine samples with the support of the Turkish Cooperation and Coordination Agency (TIKA), returning a date in the tenth century CE (Баярсайхан & Энхбат 2017; Onar et al. 2019).

Though other rock burials and other textiles have been found in Mongolia, the finds from Üzüür Gyalan stand out for the degree of their preservation. The abundance of woven wool in the assemblage is also striking; so far, the few complete garments from the Medieval period found in Mongolia have been made of silk (Oka 2009), with the notable exception of a felt *deel* and fragments of a sheepskin deel from the rock burial site of Dugui Tsakhir (Эрдэнэбат & Амартүвшин 2014). Incidentally, these *deel* have also been dated to the tenth century. Fragments of wool fabric are common in rock burials but they are seldom accessioned into institutional collections after recovery and have not yet been subject to systematic analysis. Naturally coloured striped wool textiles bearing at least superficial resemblance to some of the textiles from Üzüür Gyalan have been reported at other Medieval rock burial sites including Zavkhan Erdenekhairkhan (Баярсайхан & Түвшинжаргал 2016) and Tsagaan Khad (Ahrens et al. 2015). One of the major questions addressed here is whether or not the Üzüür Gyalan woven wool textiles were produced locally by nomadic pastoralists in the Altai (fig. 4).

Materials and methods

The inherent constraints on woven textile technology (there are only two directions in which to spin fibres into a single thread and only a handful of basic weaves)

Fig. 6: Brown *deel* (photo/line drawing composite). This is the most heavily patched of the fabric *deel,* with patches on the body and proper right sleeve that would have been visible when it was worn. The brown outer fabric, though it appears monochrome from any distance, actually incorporates subtle horizontal warp stripes. While it is conceivable that subtle *vertical* stripes could occur unintentionally if the warp thread was spun from variegated wool, horizontal stripes must be built into the warp deliberately by alternating dark and light threads (Image: Kristen Pearson)

can make the development of reliable typologies difficult, especially for technically simple fabrics. In order to overcome these difficulties, textile typologies must take into account a full reconstruction of the textile *chaîne opératoire*, the sequence of steps that go into producing an object. Textiles are particularly suited to this kind of analysis because every step in the production sequence is readily discernible in the final product. Peters (2012) refers to textiles as an "agglutinative" technology for this reason.

This study relies on standard techniques of textile analysis based on observation with the naked eye and a hand-held digital microscope at 50 x. Data such as thread count, spin direction and thread structure, thread diameter, weave structure, etc. were recorded for every unique piece of woven wool and cotton fabric in the assemblage: in total 80 pieces spread over 16 objects (table 1). Unique pieces were defined as demonstrably distinct instances of weaving: separate but adjacent pieces of fabric in one object which matched in thread count and appeared visually indistinguishable (most of the tailored components of the *deel*, for instance) were recorded only once to avoid skewing the data towards larger pieces (table 1, figs 5 to 8).

Fig. 7: Patchwork trousers (photo/line drawing composite). These are constructed entirely from patchwork fabric of 23 different pieces applied to a lining of patchwork felt. Why did someone go to the trouble of stitching a garment from so many pieces and why did they do so in such an obviously haphazard way? A purely economic explanation is not satisfactory given the treatment of fabrics, scraps, and patches in the assemblage as a whole (Image: Kristen Pearson)

Consistency and variation in the assemblage

Nomadic weaving traditions are well documented in western Central Asia. These include the pile carpets of Iranian nomads (Huang 2014) and the flatweave rugs (kilims) of Turkic nomads (Krody et al. 2018). These traditions make it clear that weaving and pastoral nomadism are compatible activities, that sophisticated weaving can be accomplished on fully portable looms, and that weaving carried out in mobile pastoralist households is able to not only meet the domestic needs of a family, but also create surplus value. Despite all this, the possibility that weaving may have played an important role among ancient and Medieval nomads in Mongolia has not yet received serious consideration. The wool fabrics are the focus of this study including analyses of how fabrics were produced and how they were incorporated into other objects. First, it is helpful to establish a point of comparison with those materials whose origins are less controversial: local felt, fur, and leather on the one hand and non-local cotton and silk on the other.

Felt is the prototypical fabric produced by Eurasian mobile pastoralists and has been attested archaeologically as early as the Iron Age in the Pazyryk burials in the Altai (Bunn 2010; Rudenko 1970). Ethnographic studies conducted in Mongolia and southern Siberia all emphasise the communal nature of feltmaking (Vainshtein 1980; Kazato 2012; Portisch 2011). Unlike woven wool textiles, which can be produced by a single person and may require days, weeks, or even months of labour, felt requires the labour of many individuals over a short period of time. It is not a regular activity, but an annual or twice-yearly one, generally occurring over a period of a few days in the summer or early autumn. Felt is produced by rolling wool inside a piece of old felt, a reed mat, or a large dehaired animal hide, which determines the finished size and shape of the felt. The felt is then cut into other shapes as needed, as it will not fray. The long wool from animals sheared in the spring produces thick felt ideal for rugs and ger walls, while the shorter wool from an autumn shearing or from lambs produces fine, flexible felt that can be used in clothing. Both kinds of felt are present in the Üzüür Gyalan assemblage. The felt linings of the red, tan, and brown *deel* are stitched together from several pieces. This is necessary to create a flexible garment, but it also allows for the incorporation of cuttings from

Fig. 8: Red and tan trousers (photo/line drawing composite). These have been patched on both sides, reflecting their extensive use. The only pieces of clothing in the assemblage that do not have evident signs of repair are the red *deel* and the brown and tan trousers; the garments the deceased was wearing when buried (Image: Kristen Pearson)

felt sheets that are produced only occasionally, stored, and used as needed.

The significance of fur and leather in early nomadic pastoralist societies is also well established, with examples dating back to the Iron Age. One of the four Üzüür Gyalan *deel* is made from animal skins - sheep and probably goat. The tailoring is similar to that of the fabric *deel* (see below), with triangular gussets cut from hide. Comprehensive fibre analysis of the wools and furs in the assemblage and an ethnoarchaeological study of the skin *deel* are ongoing. Soft furs from small mammals are also represented. Pika (*Ochotona sp.)* fur has been identified in the lining of the felt and cotton hat and fox (*Vulpes sp.)* fur on the collar of the tan *deel* using transmitted light microscopy.

Symmetrical cut-outs of thin leather with teardrop and trefoil shapes were amongst the materials in the sewing kit. Their intended use is suggested by the leather appliqué decoration on the silk headdress: a row of four delicate palmate shapes, each element linking to the next in the manner of a paper doll chain. Similar leather appliqués, used to decorate a leather quiver, are known from the 14th century Tsagaan Khad burial mentioned earlier (Ahrens et al. 2015). Finally, leather appears in more utilitarian contexts such as on the cuffs of the brown and tan *deel*, a treatment that would have reinforced the wear-prone sleeves.

Unlike wool or animal hides, silk and cotton cannot be cultivated or collected in the Altai or the surrounding steppe. Both of these materials occur in the Üzüür Gyalan assemblage, but they make up only a small fraction of the total fabric. Silk objects include the woman's veil, eye mask, and headdress, which is made of several squares of mismatched tabby and twill silk pieced together. Small pieces of complex polychrome silk were used for the collars and armpit gussets of the red *deel* and a fragment of samite (polychrome compound twill) with a Tang/Liao peony pattern had been ripped into three pieces and put inside the woman's boot. The samite piece is certainly from China, whereas the other silks could be from China or Central Asia.

There are six instances of cotton fabric in the assemblage, all used as patches except for one: a hat made from felt, pika fur and cotton. This hat has two layers, which can be completely separated from each other. The upper layer is of fine brown felt, shaped like a hood. The inner layer is made from two pika skins with the fur facing inwards, the skin side covered by cotton fabric. The fact that the inner layer is itself finished with fabric suggests that the hat was designed so it could be worn in three different ways (felt, fur and cotton, or both together) perhaps for different seasons. The cotton fabrics are notable for their balanced weaves, contrasting with the wool fabrics. They are all plain tabby weaves with tightly overspun warps and wefts and relatively low thread counts. Three have s/s spin, one s/z, and two z/z. Further study is necessary to determine the origin/s of cotton in Medieval Mongolia. By the tenth century, the Central Asia city states were cultivating cotton, but it was not yet grown in China (Dale 2009).

In abundance and a variety of applications, the woven wool fabrics in the Üzüür Gyalan assemblage more closely resemble felt and leather than silk and cotton. Woven wool fabric, often in combination with felt or animal hide, comprises the bulk of both clothing and non-clothing textiles, whereas cotton and silk are used as patches, trim, or for small items such as hats and headdresses. The sheer quantity of the woven wool textiles, with multiple sets of clothing included in a burial that would not otherwise be characterized as "rich", suggests that woven wool was an easily attainable material. Further, wool fabric is frequently used in redundant ways – to face a felt saddle blanket, for example – and for objects and clothing that could just as easily have been made of felt or leather, such as saddle bags.

As an assemblage, the wool textiles demonstrate a degree of consistency suggestive of production within a coherent tradition. However, without a substantial body of evidence with which to compare these materials, the geographical and temporal parameters of such a tradition and the factors responsible for variations within them cannot be established.

Fabric type

The wool fabrics are all in tabby weave, with the exception of two fragments in half basket weave. In all cases but two, singles are used for both warp and weft. Whenever both weft selvedges are preserved, the fabric was woven in strips no more than 31 cm wide. This indicates the use of a narrow loom. Weaving errors, which occur at least once in most of the objects, indicate that the looms were equipped with heddles. There are no warp selvedges, starting borders, corded edges, fringes, etc. Loose edges were enclosed in seams or hems. Most of the weaves are unbalanced or faced, with a dominant warp in every case where it is possible to distinguish between the two thread directions. Finer fabrics are generally more unbalanced than coarser fabrics. The threads in the dominant direction (warp/series 1 in table 1) are generally more tightly spun than the threads in series 2, so it is likely that the dominant direction does in fact correspond to the warp in most, if not all, the fabrics.

Spin directions

Sewing threads are z-spun, S-plied without exception. Embroidery threads are all loosely spun s. In woven fabrics, the spin-direction is conservative in the warp threads, which are z-spun singles with three exceptions, where warps are plied (two of these occur in a girth and one in the strap attached to the red and tan trousers, so the plied warps could be functional). Weft spin direction appears to be more complicated: in 38 cases the wefts are z-spun singles, while in 30 they are s-spun singles. One of the remaining fabrics in the girth has plied wefts in addition to its plied warps. Another is a checked fabric with z-spun brown wefts and s-spun white wefts, and three are fabrics with infrequent and apparently random alternation between z and s-wefts. These are instances where the weaver began using a differently spun skein of weft thread partway through the weaving process. This may actually be a more widespread practice than the data represent, since the majority of individual pieces of fabric, particularly the patches, are small and unlikely to capture alternations occurring over several metres of weaving. As all of these fabrics are warp dominant or faced, switching the weft spin would have no visual effect like that seen in spin-patterned twills.

Fig. 9: The white selvedges of the brown deel. Note also the generous seam allowances, the consistent pairing of selvedges with cut edges, and the rough hemming of cut edges with overcast stitched – all features of tailoring that are consistent throughout the assemblage. (Image: Kristen Pearson)

Stitching

There are five types of stitch used in the assemblage, each exclusively in a specific context. Overhand stitch is used to join pieces of felt or leather, cross-knit looping stitch is used to reinforce felt edges and hem cut edges of fabric, running stitch is used to sew woven fabrics, and chain and loose satin stitch are used for embroidery.

Stripes and checks

While most of the fabrics are monochrome, there are a few examples where stripes or checks are created, taking advantage of natural variations in wool colours. One-row-wide horizontal stripes are formed in warp-faced fabrics by alternating colours in the warp, so that on one pass only warps of one colour are visible, and on the next, only warps of the other colour. Vertical stripes are also built into the warp with larger sets of differently coloured warp threads. Horizontal and vertical stripes can be combined in the same piece. A checked pattern is formed when weft stripes are combined with vertical warp stripes in a more balanced tabby. These patterning techniques can be very dramatic or very subtle depending on the range of colours used.

Double/triple warps

Random cases of thread doubling are usually considered a weaving flaw (and a useful one, because they can help distinguish warp and weft and indicate the use of heddles). These weaving flaws do occur, as described above, but doubled or tripled threads also appear in sets (up to seven pairs of doubled threads in one weft pass) or in a repeating pattern. Sometimes they run the whole length of the fabric, indicating a variation encoded in the warp set-up, but in some cases the stripes occur for only five to ten weft passes. The sets of doubled or tripled warps create a subtle but noticeable variation in texture (fig. 11).

Selvedge marking

The fine fabrics of the brown and tan *deel* were woven with lighter coloured threads in the outermost warps, which has the effect of marking the selvedges with a thin stripe (fig. 9). The selvedges are not differentiated in any other way. In Medieval western Europe, the selvedges of tabby fabrics were frequently reinforced with cords or a sequence of doubled warps in a different colour than the body of the fabric (Crowfoot et al. 2006, 48-49). Researchers have speculated about a possible meaning encoded in the number or colour of selvedge threads, such as fabric quality, workshop or origin, and selvedge marking is associated with workshop rather than household production. It is unclear what the purpose of a selvedge marking could be in the context of the Üzüür Gyalan assemblage. A scrap of plain tan fabric used as a patch on one of the striped bags has a similar white selvedge. It does not match the fabrics of the tan *deel* in thread count, so it is not an offcut of the same piece, but it may represent a scrap taken from a similar garment.

Thread count

Whenever decorative elements are incorporated into the weaving, the weaver set up the pattern entirely by eye, without counting threads. The thread diameter is somewhat inconsistent so this may have ensured a more regular appearance to the final pattern. Stripes and checks, for example, vary in thread count but are of consistent widths when measured.

Embroidery

Three objects feature colourful embroidery with loosely spun wool threads – the "Adidas Boots", an embroidered saddle blanket, and a small leather bag. All embroidery threads are s-spun, which emphasises their contrast against fabrics faced with z-spun threads.

Colour

Natural variation in wool colour, which can range from white to dark brown or black in Mongolian sheep, goat and yak, was used for aesthetic effects as described above. For the finest fabrics, wools were assiduously sorted for consistency in colour. Coarser fabrics generally contain threads with mixed light and dark fibres. Sometimes, fibres of different colours were purposefully spun or felted together to create a variegated pattern. The felt bag was made of mixed dark brown and black wools, with light wool scattered over the surface. Several fabrics were also dyed, and it is possible that some of the fabrics that now appear shades of brown were dyed with less stable compounds that have now faded. The most common surviving colour is light red/pink, which may have been more vibrant originally. The only other colour to occur on more than one object is a bright blue, which appears on two objects: the felt shroud and the embroidered saddle blanket. On the felt shroud, designs were applied to the surface primarily in red wool; blue appears as small, bright spots forming the centre bosses of the quatrefoil motifs. Not only was it applied in such a limited area, but it was applied very thinly compared to the red, indicating that it was a rare colour and had to be used sparingly. Dye analysis is ongoing.

Construction of the garments and other objects

Tailoring traditions are closely intertwined with the weaving traditions that produce the fabric to be tailored. In some traditions, woven garments were not tailored, but were used straight from the loom with only minimal modification (Rösel-Mautendorfer 2018). The choice to weave a certain length and width of fabric is made with reference to its intended use. In urban workshop settings in Roman Egypt, tunics were woven to a set of standard sizes for men and women (Morgan 2018). But in contexts where a weaver was producing clothing for her own household, the dimensions of the weaving may correspond to the measurements of known individuals. The loom used and the method of attaching the warp ends also puts limits on the dimensions of the fabric. Portable looms, whether body tensioned or fix tensioned, produce narrow widths of fabric. Garment traditions built around the products of such looms use the narrow strips in regular and efficient ways to construct articles of clothing. The textile tradition of the Rupshu pastoralists in Ladakh, Tibet, described in detail by Monisha Ahmed (2002), provides an excellent case study in a living, mobile pastoralist tradition. In Ladakh, outer garments, blankets, and saddlebags are all constructed from strips of fabric between 25 cm and 35 cm in width. The finer fabric for the outer garments is woven to the length required for a specific person, and garments are constructed using traditional patterns that make use of the narrow loom-widths, where possible, as well as triangular pieces. Blankets and bags are all made from loom-widths stitched selvedge to selvedge, with three conventional sizes of bags defined by the number of loom-widths used in their construction (see below).

The Üzüür Gyalan wool *deel* and two of the three pairs of trousers (the third is made entirely from patchwork; fig. 7) are constructed from loom-widths and strips that are slightly tapered combined with triangular and trapezoidal pieces. Ahmed does not state whether the triangles used in Ladakhi tailoring are cut in such a way that one selvedge is preserved, but this is frequently the case in the Üzüür Gyalan material.

The three wool *deel* are tailored following the same basic pattern: the A-line body with right-over-left overlapping flaps is built from full and tapered loom-widths arranged vertically and inset with gussets. The triangular shape of the gusset can be pieced together in different ways in order to make use of the available fabric, including offcuts from other textiles. Mismatched offcuts are only used on the hidden inside flaps of the *deel*. Seam allowances are generous – at least 1 cm and up to 2.5 cm – another indication that woven wool fabrics were not of especially high value to the people making the garments. The sleeves are constructed from three tapered strips arranged vertically.

The red *deel* and the brown *deel* are lined in the centre with felt, while the tan *deel* is lined in the centre with sheepskin. Full and tapered loom-widths of coarse woolen fabric are used as a lining around the edges. In the red *deel* and brown *deel*, the loom-widths are arranged horizontally on the bottom edge and vertically along the flaps, which is the most efficient use of the fabric in terms of the sewing time. On the tan *deel*, where the central lining is limited in area by the size of the sheepskins, the lining on the bottom of the *deel* is made from ten rectangles of checked fabric applied vertically. This creates a lining that is 4 cm wider than it would have been if the original strip, which was 23 cm wide from selvedge to selvedge, had been used horizontally.

The trousers are constructed from a single loom-width arranged horizontally and attached to legs made from loom-widths and a crotch made from two triangles. They are perhaps more properly described as one-piece suits, as the top section is equipped with a strap that must have gone over the wearer's shoulder. Similar garments made from silk and described as "underwear" have been found in Khitan-Liao tombs in Inner Mongolia (Watt et al. 1997). Experimental reconstruction may shed light on how this unusual garment was worn. Other wool textiles – the saddle bags, the saddle blankets, and the pile textile are made exclusively from loom-widths. In the case of the saddle blankets, the loom widths are stitched over a thick felt base, leaving a "window" for the saddle.

Fig. 10: Pile fabric. The function of this textile is unknown, although the plushiness imparted by the long pile suggests a blanket or shawl. The supplementary weft that forms the pile was spun in several segments rather than one continuous yarn, and in a few places the tail end of a segment has come loose and hangs off the selvedge edge (Image: Kristen Pearson)

The woven wool fabrics in the Üzüür Gyalan burial appear to have been manufactured in a fairly consistent tradition and applied to the construction of objects in ways that demonstrate their abundance and their familiarity to those working at later stages in the *chaîne opératoire*. The people who constructed garments and other objects for use by the Üzüür Gyalan woman and her community seem to have had access to a regular supply of woven wool fabrics from a single or limited number of sources. They knew what to expect from these woven wool fabrics and created a garment and object crafting tradition around the reliability of those expected sources. Either the textiles were produced in a specialised setting which allowed them to be sold relatively cheaply and on a reliable basis to nomadic pastoralists who did not weave or they were produced in nomadic households.

Fig 11: Pile fabric (detail) (Image: Kristen Pearson)

Towards the identification of a nomadic tradition

While the distinction between household and workshop production of textiles is not always straightforward, certain criteria can be used to suggest one or the other alternative. Household production, whether assessed through the textiles themselves or the tools used to make them, is likely to involve a wide range of non-standardised fabric qualities woven for different functions (Brandenburgh 2010; Øye 2014). In addition, textiles produced in the household might show signs of imperfect planning, particularly if a weaver is attempting a new or only infrequently applied technique. A professional weaver, working on a standardised product, knows exactly how much material to prepare, how much space to leave for this or that motif, etc., whereas a household craftswoman might produce a weaving experimentally or expediantly and keep the less-than-perfect results. The pile textile (fig. 10 and fig. 11) from Üzüür Gyalan points to this kind of imperfect planning. It was woven in one piece, with a z-spun warp of pink wool and wefts that are sometimes brown, sometimes pink, sometimes z-spun, sometimes s-spun in no discernible pattern. Because this textile is warp dominant, the result is a pink textile with subtle areas of pink-brown shading where the brown weft shows through. The pile is formed with a supplementary weft inserted at intervals between several rows of tabby. It is not knotted; loops are formed by pulling short lengths of the supplementary weft out of the woven matrix and allowing the overspun yarn to ply back on itself. The weaver pulled out rather generous lengths at first, creating a soft, thick pile but, as she approached the end of the weaving, she began to run out of yarn; the loops get smaller and smaller and are spaced further and further apart. The last 15 cm were woven without any pile. The weaver removed the fabric from the loom, cut it into three equal sections, and stitched the sections together selvedge to selvedge with the last third of the weaving in the middle. Evidently, she was not troubled by her mistake – at least not enough to justify wasting the last 20 cm of warp (fig. 10 and fig. 11).

If the Üzüür Gyalan woven wool textiles were indeed produced in the context of nomadic households, what other evidence might be found? The ways in which mobility shapes a nomadic textile tradition in the present day are instructive as are comparisons drawn between ethnographic and archaeological material. Ahmed's study of Rupshu weaving, previously mentioned in the context of tailoring, provides one example of how a substantial investment in weaving can be integrated with a mobile pastoralist lifeway. A direct comparison between weaving in present-day Tibet and weaving in the Medieval Altai is not suggested here; rather, Ahmed's observations on labour investment, timing, and seasonality may help explain some of the features observed in the Üzüür Gyalan assemblage.

In Ladakh, men and women spin year-round during spare moments, but especially during the winter. In contrast, weaving can only be done in the summer when it is warm enough to work outside. Enough coarse fabric for two small bags or one medium-sized bag can be woven in a single day if the thread has already been spun, whereas larger bags or blankets will take two or three days to complete. The strips of fabric used to construct bags and blankets are always woven as one piece, a labour-saving strategy as it consolidates the process of laying out the warp. Ahmed stresses the fact that woven bags are constantly in demand, that they experience heavy wear requiring reinforcements of felt, and that they are woven quickly and as needed. The two woven saddle bags from Üzüür Gyalan are riddled with weaving errors and have been heavily and not very carefully patched (fig. 12).

In contrast to the coarse fabrics for bags and blankets, Ahmed tells us it takes two to three weeks of work to weave enough of the much finer *snam-bu* fabric for one person's robe. She does not give the exact dimensions but she states that the length of the warp required for a garment can range from 36 to 44 *mtho*, a unit described as the distance between the ends of the middle fingers and thumb when the thumb is outstretched. The width is about 30 cm. If the *mtho* is estimated at 20 cm, then between 7.2 m and 8.8 m of warp must be laid for one robe (2.16 to 2.64 square metres). She states further that the *snam-bu* is woven in lengths called *bubs*, and

Object	Function and location of fabric	Material	Binding	Thread count (weft or series 1/warp or series 2)	Thread structure (weft or series 1/warp or series 2)	Thread diameter (weft or series 1/warp or series 2)
Brown *Deel* (Figure 6)	Brown outer fabric	Wool	Tabby	10x20	z&s/z	0.2-0.3/0.2-0.3
	Brown outer fabric (inset: inner flap)	Wool	Tabby	6x9	s/z	0.4-0.6/0.7-0.9
	Brown outer fabric (inset: inner flap)	Wool	Tabby	7x12	s/z	0.4-0.6/0.4-0.6
	Brown outer fabric (inset: sleeve)	Wool	Tabby	7x20	s/z	0.4/0.4
	White lining	Wool	Tabby	6/9-13	s/z	0.5-1.2/0.5-1.2
	Checkered lining (inset)	Wool	Tabby	9x11	s/z	0.3-0.4/0.5-0.8
	Red lining (inset)/patch (sleeve)	Wool	Tabby	7/11-14	s/z	0.3-0.7/0.4-0.8
	Trim/patch (collar)	Cotton	Tabby	10x11	s/s	0.2-1.0/0.2-1.0
	Trim/patch (collar)	Wool	Tabby	12x16	s/z	0.2-0.3/0.2-0.3
	Patch (breast)	Wool	Tabby	7x11	s/z	0.2-0.9/0.2-0.9
	Patch (body)	Wool	Tabby	12x13	z/z	0.1-0.3/0.1-0.3
	Trim/patch (collar)	Cotton	Tabby	7x8	z/z	0.2-0.8/0.2-0.8
	Patch (lining, hem)	Wool	Tabby	10x23	s/z	0.3-0.4/0.3-0.4
Red *Deel* (Figure 4)	Red outer fabric	Wool	Tabby	13x34	s/z	0.1-0.2/0.2-0.3
	White lining	Wool	Tabby	6-8/16-20	s/z	0.5-0.7/0.5-0.7
Tan *Deel* (Figure 5)	Tan outer fabric	Wool	Tabby	7x21	s/z	0.2/0.3-0.4
	Checkered lining	Wool	Tabby	5x10	z&s/z	0.6-1.2/0.6-1.2
	Red trim (collar and sleeves)	Wool	Tabby	9x26	z/z	0.2/0.3
	White lining	Wool	Tabby	6x14	z/z	0.8-1.2/0.8-1.2
	Tan outer fabric (inset: body)	Wool	Tabby	11x33	z/z	0.2/0.2
	Patch (front)	Cotton	Tabby	10x12	s/s	0.3-1.2/0.3-1.0
	Patch (back hem)	Wool	Tabby	11x33	z/z	0.2-0.3
	Red outer fabric (inset: body)	Wool	Tabby	8x14	s/z	0.5-0.7/0.5/0.7
Hide *Deel*	Orange patch (body)	Wool	Tabby	5x9	z/z	0.5-0.8/0.5-0.8
	Orange patch (body)	Wool	Tabby	14x18	s/z	0.5/0.5-1.0
	Brown patch (body)	Wool	Tabby	6x7	s/z	0.4-0.6/0.4-0.6
	Tan patch (body)	Wool	Tabby	9x22	z/z	0.3-0.4/0.3-0.4
Embroidered Saddle Blanket (Figures 1, 2)	Red facing	Wool	Tabby	8x12	z/z	0.4-0.5/0.4-0.5
	Brown facing	Wool	Tabby	10x11	s/z	0.3-0.4/0.4-0.6
Saddle Blanket	Red facing	Wool	Tabby	7x13	z/z	0.4-0.5/0.5
	Red facing	Wool	Tabby	8x12	s/z	0.4-0.5/0.5
	White backing	Wool	Tabby	8x12	s/z	0.4-0.6/0.4-0.6
	(?) dark red associated fragment	Wool	Tabby	7x14	z/z	0.5/0.6
Pile Textile (Figures 10, 11)	--	Wool	Tabby w/pile	3x8	z&s/z	1.5-2.0/0.9-1.2
Striped Bag (1)	--	Wool	Tabby	5x18	z/z	0.7-1.3/0.4-0.6
	--	Wool	Tabby	7x22	z/z	0.4/0.4

Table 1: Technical data of the textiles from Üzüür Gyalan

Object	Function and location of fabric	Material	Binding	Thread count (weft or series 1/warp or series 2)	Thread structure (weft or series 1/warp or series 2)	Thread diameter (weft or series 1/warp or series 2)
Striped Bag (1)	--	Wool	Tabby	6x18	z/z	0.4/0.4
	--	Wool	Tabby	5x18	z/z	0.5-0.6/0.4-0.5
	Patch	Wool	Half-basket	3x12	z/z	1.0-1.1/0.6
	Patch	Wool	Tabby	6x17	s/z	0.4-0.6/0.4-0.6
Striped Bag (2)	--	Wool	Tabby	4x10	z/z	1.0-1.2/0.9-1.9
Red and Tan Trousers (Figure 8)	Tan outer fabric	Wool	Tabby	8x24	z/z	0.2/0.4
	Red outer fabric	Wool	Tabby	9x23	z/z	0.4-0.5/0.4/0.5
	Tan patch (leg)	Wool	Tabby	7x18	z/z	0.2/0.4
	Tan patch (leg)	Wool	Tabby	8x20	s/z	0.2/0.4
	Red patch (body)	Wool	Tabby	12x16	z/z	0.3-0.4/0.3-0.4
	Strap	Wool	Half-basket	8x11	Z(?)/S(2z)	0.4/0.5
	Strap	Wool	Tabby	7x14	z/z	0.5-0.8/0.5-0.8
Tan and Brown Trousers	Tan outer fabric (legs)	Wool	Tabby	10x18	z&s/z	0.4-0.5/0.4-0.5
	Brown outer fabric (body)	Wool	Tabby	10x31	s/z	0.2-0.3/0.2-0.3
Patchwork Trousers (Figure 7)	Patch	Wool	Tabby	9x24	z/z	0.2-0.4/0.2-0.4
	Patch	Wool	Tabby	9x19	z/z	0.3-0.4/0.3-0.4
	Patch	Wool	Tabby	8x19	z/z	0.2-0.4/0.2-0.4
	Patch	Wool	Tabby	8x10	s/z	0.3-0.4/0.3-0.4
	Patch	Wool	Tabby	10x27	s/z	0.3-0.6/0.3-0.6
	Patch	Wool	Tabby	10x23	s/z	0.2-0.3/0.2-0.3
	Patch	Wool	Tabby	9x21	z/z	0.2-0.4/0.2-0.4
	Patch	Wool	Tabby	7x10	s/z	0.3-0.6/0.3-0.6
	Patch	Wool	Tabby	9x26	z/z	0.3-0.5/0.3-0.5
	Patch	Wool	Tabby	9x22	z/z	0.2-0.4/0.2-0.4
	Patch	Wool	Tabby	5x11	s/z	0.9-1.2/0.9-1.2
	Patch	Wool	Tabby	9x20	z/z	0.4/0.4
	Patch	Wool	Tabby	7x10	z/z	0.5-0.8/0.5-0.8
	Patch	Wool	Tabby	5x11	s/z	0.8-1.2/0.8-1.2
	Patch	Wool	Tabby	7x14	z/z	0.3-0.4/0.3-0.4
	Patch	Wool	Tabby	9x20	z/z	0.4-0.6/0.4-0.6
	Patch	Wool	Tabby	5x19	z/z	0.3-0.4/0.3-0.4
	Patch	Wool	Tabby	9x23	z/z	0.3-0.4/0.3-0.4
	Patch	Wool	Tabby	8x21	z/z	0.3-0.4/0.3-0.4
	Patch	Wool	Tabby	8x12	s/z	0.5-0.6/0.5-0.6
	Patch	Wool	Tabby	17x18	s/z	0.4-0.7-0.4-0.7
	Patch	Wool	Tabby	10x28	s/z	0.3-0.4/0.3-0.4
	Patch	Wool	Tabby	8x14	z/z	0.7/0.7
Felt and Fur Hat	Lining	Cotton	Tabby	12/13	s/s	0.2-0.6/0.2-0.6
Girth (Figure 1)	--	Wool	Tabby	3x8	S(2z)/S(2z)	2.0/2.0
	--	Wool	Tabby	4x6	z/S(2z)	0.8/1.2-1.5
	--	Wool	Tabby	5x14	z/z	0.5/0.7-0.9
Headdress	--	Cotton	Tabby	8x8	z/z	0.2-0.6/0.2-0.6
Patchwork hat	Patch	Cotton	Tabby	15x15	s/z	0.5/0.5
	Patch	Wool	Tabby	18x21	z/z	0.2-0.3/-.2-0.3

Table 1 **(**continued): Technical data of the textiles from Üzüür Gyalan that two or more *bubs* may be necessary to produce a garment for a larger person. She does not record how the length of a *bub* is determined or if it can vary.

The tapering and gussets of the Üzüür Gyalan *deel* make it difficult to provide a precise measure of the length of the fabric strips involved (as with the trousers, experimental reconstructions would be a helpful next step) but it is estimated that about 10 m of 22 cm wide fabric (2.2 square meters) were used in the outer construction of the tan *deel*.

Ahmed does not give full thread counts for the *snam-bu*, but she tells us that 160 plied threads are used for the warp. This would correspond to 11.2 singles per cm, significantly coarser than the outer fabrics of the Üzüür Gyalan *deel*. Without experimental data and more accurate measurements of the quantity of fabric involved, it would be premature to speculate on the time required to weave the fabric for the *deel* but it can be assumed that it would take longer than the two to three weeks taken to the weave the *snam-bu*. This provides a possible explanation for the use of *bubs*, that is, lengths of fabric that are shorter than that ultimately required for a single garment. As noted earlier in relation to the bags, it is more efficient to warp a loom once and weave a longer strip of fabric than to warp a loom twice and weave two shorter strips. This is why, in Rupshu, coarse fabrics are woven in maximally long units. What is not needed immediately might be stored for future use, just as felt is made all at once, stored, and used as needed. Indeed, woven fabric is far more efficient to store and transport than unprocessed wool. This might provide an additional incentive for mobile pastoralists to convert wool into coarse, multipurpose fabrics without first identifying a specific use for them.

Note that a coarse checked fabric was used along with sheepskin to line the tan *deel* which was 4 cm short of the width required to complete the lining. It is clear that it had not been woven specifically for that *deel*. One can imagine the frustration of the craftswoman upon realising that the available fabric would not be sufficient. Rather than weave another length of fabric 27 cm wide – entailing at least a day's work if she had the thread on hand, and several days if not – she found a way to make do with what she already had even at a minor cost to efficiency.

Fine, time-consuming fabrics are woven not in maximally long units but in the minimally long unit required for a specific individual's garment. If this minimum unit is too long, the fabric is woven in the even smaller unit of a *bub*.

Üzüür Gyalan's brown *deel* was woven in less-than-maximal units with the outer fabric consisting of at least two, possibly three nearly identical fabrics. This can be determined only because the damage to the lining permits a view of many of the selvedges in the upper, more intensively tailored section of the *deel*. One selvedge is plain brown, while several others are marked with white stripes. Selvedges with eight white threads and selvedges with ten white threads are visible.

The bottom portion of the *deel*'s felt lining is intact, making it impossible to see both selvedges on any full width of fabric. But the presence of three different selvedge patterns indicates that the fine, dark brown fabric could not have been woven in just one piece. To borrow the Rupshu terminology, it was woven in at least two *bubs*.

One possible explanation could be the need to fit weaving into mobile habitation cycles. Narrow body tensioned and fixed tension looms are portable in the sense that they are not bulky or heavy, and an unfinished weaving can be carefully rolled for storage overnight. However, transporting an unfinished weaving on the loom is likely to result in inconvenient tangles and snags at best and irreparable damage at worst. Huang (2014) gives an account of a Qash-qua'i nomad woman in Iran who had attempted to transport an unfinished weaving to a new campsite: "She wove half the carpet in winter pastures, dismantled the loom, rolled up the weaving still attached to the end beams and the heddle rod *(kujay*), and rebuilt the loom after migrating to summer pastures. 'I'll never make that mistake again' she reflected as she felt the ridges and uneven edges" (Huang 2014, 80).

The Üzüür Gyalan textiles and the Rupshu textiles are not very similar from a technical perspective. Rupshu threads for weaving are all plied, and the weave used is an extended tabby with doubled warps. *Snam-bu* is evidently coarser than the fabric used in the *deel* outer layers, and it is also fulled and napped. Apart from the use of narrow looms, the Üzüür Gyalan and Rupshu textiles bear only superficial resemblance to each other; rather, it is the way the fabrics are used in the construction of garments - and the decision-making processes surrounding what to weave and how much – that suggest an underlying similarity between the two traditions.

In this paper, we have argued that the wool textiles from Üzüür Gyalan represent a weaving tradition based in mobile households. Much work remains to develop this hypothesis further and to consider its ramifications for other time periods in the long history of the steppe. We hope that this study will encourage scholars working in the region to take a closer look at textile finds from old and new excavations alike. Archaeological research in Mongolia over the last two decades has pushed back against essentialising narratives that described mobile pastoralism as a static and marginal way of life. Textiles have a role to play as these important arguments continue to unfold, deepening our understanding of nomadic lifeways, political trajectories, and the economies of the past because "mobile pastoralist" should also modify economies here.

Mongolian summary

Товчлол:Энэхүү өгүүлэлд Монгол улсын Алтайн уулсын Үзүүр гялаан хэмээх газраас олдсон 10 дугаар зууны үед хамаарах хадны оршуулгаас илрүүлсэн даавуу эдлэлүүдэд хийсэн судалгааны үр дүнг танилцуулж байна. Уг хадны оршуулгад бүрэн тоног хэрэгсэл бүхий адуу дагалдуулан тавьснаас гадна, огт хөндөгдөөгүй анхны байрлалаараа хадгалагдаж үлджээ. Тиймээс эндээс гарсан органик болон органик бус иж бүрэн олдворууд нь судалгааны өндөр ач холбогдолтой төдийгүй төрөл бүрийн нарийвчилсан судалгаа хийх ховор боломжийг судлаачдад олгож буй юм.

Маш сайн хадгалагдсан нэхмэл ноосон даавуу эдлэлийн баялаг цуглуулга нь бусад хадны оршуулгаас олдсоор байгаа торго, нэхий, эсгий хувцас хэрэглэлээс онцлог ялгаатай. Цуглуулгын тодорхой онцлог шинж чанарууд, тухайлбал, ноосон нэхмэлийн элбэг байдал, тэдгээрийн техникийн арга зохицол нь тусгай мэргэшсэн үйлдвэрлэл гэхээсээ илүү гэр ахуйн урлал, орон нутгийн үйлчдийн бүтээл болохыг харуулж байна. Бид бэлчээрийн мал аж ахуй эрхлэгчдийн үйлдвэрлэлийн цуглуулгын шинж төрхийнх нь хувьд өнөөгийн Түвэдийн Ладах мужийн нүүдэлчдийн нэхмэлийн уламжлалтай харьцуулан авч үзлээ.

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Gwendoline Pepper

Time looms over us:

Observations from an experimental comparison of medieval English loom-types

Abstract

The organisation of textile production in medieval England underwent a dramatic transition between roughly the tenth and 12th centuries. These changes, which include the formation of weaving guilds and the evolution of weaving as a male-dominated trade, are typically attributed to the adoption of a new, more efficient style of loom. In order to critically examine the role of technology during this transitional period, an experiment was designed to compare the relative efficiency of two different types of loom in use during the Middle Ages. The experiment yielded interesting timed results and experiential observations, which indicate a difference in the skill level required by each loom, suggesting a complicated relationship between gender, new technology, and the perception of skill in medieval England.

Key Words: Medieval England, weaving, time, gender, labour, looms, experimental archaeology, technology

Introduction

The process of weaving cloth is a task with heavily gendered connotations. Weaving has been viewed at different points in history as primarily a female or male activity depending on the cultural context. This paper is concerned with a point in medieval English history during which the previous association of women with weaving was switched to men.

For the purposes of this discussion, it is important to acknowledge that biological sex and gender identity are not one and the same, and neither biological sex nor gender exist as a rigid binary (Gilchrist 1997, 43; Parker Pearson 2010, 95). There is a risk of projecting assumptions about a gender binary and also in assuming which roles are carried out by a particular gender in archaeological study. The negative impact of assuming particular gender roles in a society has been discussed by Conkey and Spectre (1984), among other researchers. Written sources and archaeological material from medieval Britain and Europe do indicate a societal concept of male and female gender roles (Fell 1984, 39-40; Gilchrist 2012, 114). Even so, the rigidity of this gender binary is uncertain and burial evidence from early medieval England in particular indicates some fluidity of the gender associations of certain grave goods (Lucy 1997, 162-163). Furthermore, it is clear that there was enough flexibility in gender roles for a major shift in gendered work to take place concurrent with the industrialisation of textile production between the early and late Middle Ages.

A key variable in this transitional time for medieval English cloth production was the equipment used in the weaving process. There is substantial evidence indicating that between the tenth and 12th centuries, two new styles of loom were introduced to the British Isles and employed to produce cloth: the two beam vertical loom (fig. 1); and the horizontal treadle loom (fig. 2). The horizontal treadle loom is the better known of these two styles of loom. It is understood to have dramatically increased the speed with which a weaver could produce cloth. The increased efficiency of this loom, in contrast to its predecessor, the warp-weighted loom (fig. 3), is typically connected to the adoption of weaving as a profession by men and the commercialisation of cloth production on an international scale (Hoffmann 1974, 258; Walton Rogers 1997, 1827). While this technological transition has been the topic of previous research (Endrei 1968;

Fig. 1: A mid-12th century depiction of two-beam vertical loom in use. Cropped detail from *The Eadwine Psalter* R.17.1, f263r (Image: © The Master and Fellows of Trinity College Cambridge, reproduced with permission)

Fig. 2: A 13th century depiction of the horizontal treadle loom in use. Cropped detail from the *Romance of Alexander* O.9.34, f032v (Image: © The Master and Fellows of Trinity College Cambridge, reproduced with permission)

Henry 2005; Øye 2016), there is very little information on exactly how much more efficient this new type

Fig. 3: Artist's interpretation of the Anglo-Saxon warp-weighted loom in use (Image: Gwendoline Pepper)

of loom might have been. A previous estimate that the horizontal treadle loom produced cloth at three times the rate of the warp-weighted loom was made by Endrei (1968, 37-38) based on his own research and recorded weaving times from the early modern Icelandic *Bùalög*, which are also described by Hoffmann (1974, 215-216). Endrei's research was well reasoned using the resources available, but his estimates were not based on a direct comparison and are therefore missing crucial information, which can only be obtained by observing both looms working under similar conditions.

Experimental archaeology is the ideal way to address the question of weaving efficiency and it was with the goal of closing this gap in information that an experimental programme was developed to compare the weaving speeds of the warp-weighted loom and the horizontal treadle loom. The experiment described in this paper cannot be used to interpret the precise number of hours it would have taken a medieval English weaver to produce cloth, as there are too many variables to replicate the process accurately. However, the experimental results did provide some useful efficiency ratios, which highlight key differences between these two looms. These observed differences in efficiency have, in turn, underscored some important considerations concerning the relationship between the introduction of new technology and changing gender roles during the Middle Ages.

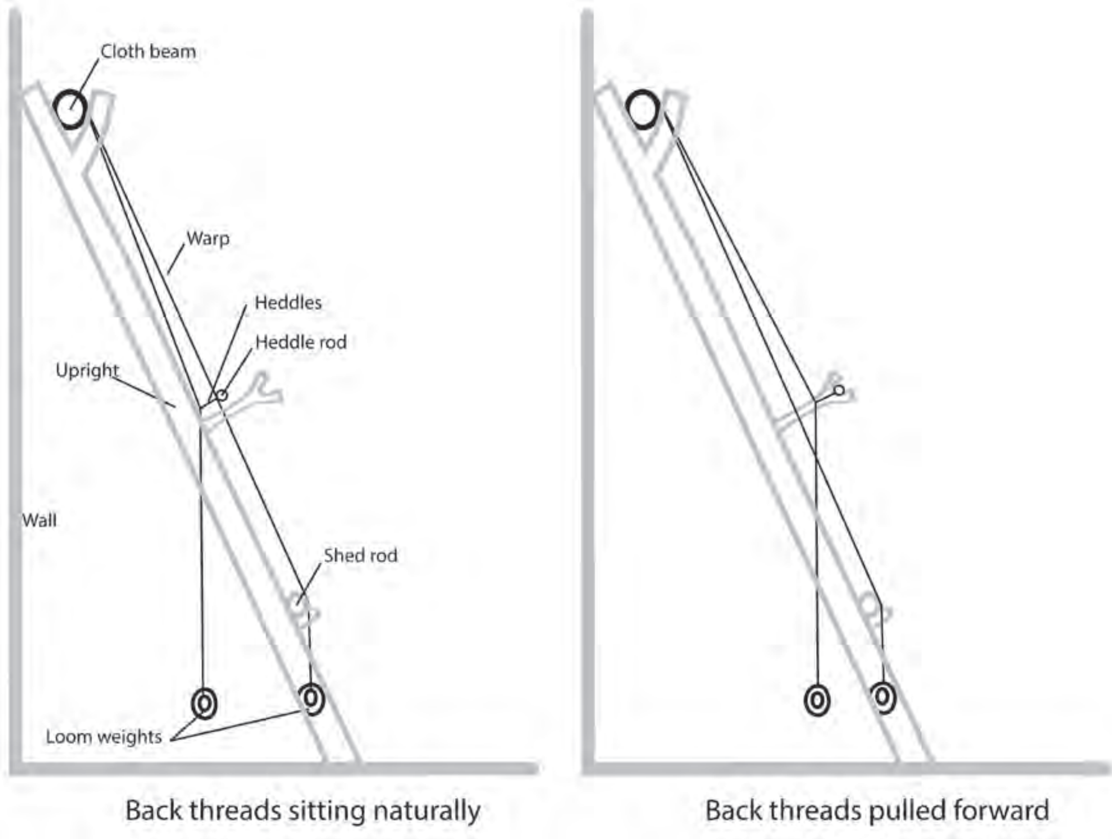

Fig. 4: Side view of tabby weave set up on the warp-weighted loom (Image: Gwendoline Pepper)

Historical context

Textile production in early medieval England is understood to have been organised and carried out primarily by women (Henry 2005, 52; Walton Rogers 2014, 253-54). This does not necessarily mean that men never participated in textile production at this time, but rather that there seems to have been an established practice in Anglo-Saxon England of women as the key textile producers (Fell 1984, 40). Cloth would primarily have been woven on the warp-weighted loom during this early period (Walton Rogers 2001, 161). This style of loom is simple in construction (fig. 4) and is often associated with the weaving of relatively wide cloth. Many surviving Scandinavian looms from the 18th and 19th centuries have widths of between 190 cm and 241 cm (Hoffmann 1974, 24-29), while a find from medieval Greenland included a beam of a warp-weighted loom measuring 188 cm (Øye 2016, 5). Øye, however, has recorded clusters of loom weights varying from one to two metres long as indications of the varying potential widths of cloth woven on this type of loom (Øye 2016, 5). Within Anglo-Saxon villages, there is extensive evidence for the practice of weaving in communal buildings, or *Grubenhäuser*, up to the tenth century. This is suggested at settlement sites including Mucking, Essex, and West Stow, Suffolk (United Kingdom), by the concentrated groupings of loom weights in specific areas of the settlements, usually inside one or more *Grubenhaus* (Walton Rogers 1997, 1823). Walton Rogers suggests that weavers would likely have worked collaboratively in this setting with multiple women working together at one loom (Walton Rogers 2014, 258).

The development of economic centres and the formation of prototowns from the ninth century onwards indicate a transition towards more commercial craft production (Henry 2005, 55). There is clear evidence of textile production in these emerging urban centres (Walton Rogers 2014, 267). Archaeological evidence from the Coppergate site in York (United Kingdom) provides fascinating insight into the changing organisation of textile production in a developing urban setting. The ninth century evidence at Coppergate indicates that textile production occurred in communal locations separate from other activities, which appears to have been a typical rural pattern for this time (Walton Rogers 1997, 1824). During the tenth century, the distribution of weaving tools indicates that production had transitioned from communal buildings to taking place within separate households. This change occurs within the same context in which loom weights are missing so it seems that this is concurrent with the introduction of the two-beam vertical loom (Walton Rogers 1997, 1824). Weaving activities appeared to concentrate in two of the tenements around the 11th century, contemporaneous with the earliest evidence for the introduction of the horizontal treadle loom in England. This indicates craft specialisation (Walton Rogers 1997, 1827) that is consistent with the suggestion that this area of the city was one of increasing commercial activity (Walton Rogers 1997, 1829). The example of Coppergate illustrates the development of an urban setting in which weaving as a specialised trade began to flourish.

The horizontal treadle loom was likely introduced to medieval England around the year 1000 CE, contemporaneous with evidence for the introduction of this loom to western Europe (Hoffmann 1974, 258; Walton Rogers 2001, 162; Øye 2016, 6). This loom was more complicated in construction and featured new developments including a built-in reed for spacing threads evenly and foot-powered treadles with which to change the shed (fig. 5). The adoption of the treadle-operated loom is also associated with the evolution of weaving into a guild-regulated trade (Hoffmann 1974, 258).

The earliest records for established weaving guilds in England date to the 12th century. The 1130 pipe roll identified five weavers' guilds in London, Winchester, Lincoln, Oxford and Huntingdon, while York's weaving guild appeared later in the pipe roll of 1165 (Carus-Wilson 1944, 42). This suggests that these organisations had already begun to form prior to the mid-12th century, potentially concurrent with the introduction of the horizontal treadle loom. The theorised connection between early weaving guilds and the introduction of the horizontal treadle loom is often accompanied by the assumption that these guilds were formed by men (Munro 2003, 195; Karras 2004, 94). This appears to be due at least in part to an association of the horizontal treadle-loom with male weavers.

There is no clear explanation of why this new type of loom is so strongly linked to male weavers, but historical sources do suggest that this was the case. One often-cited piece of written evidence for this

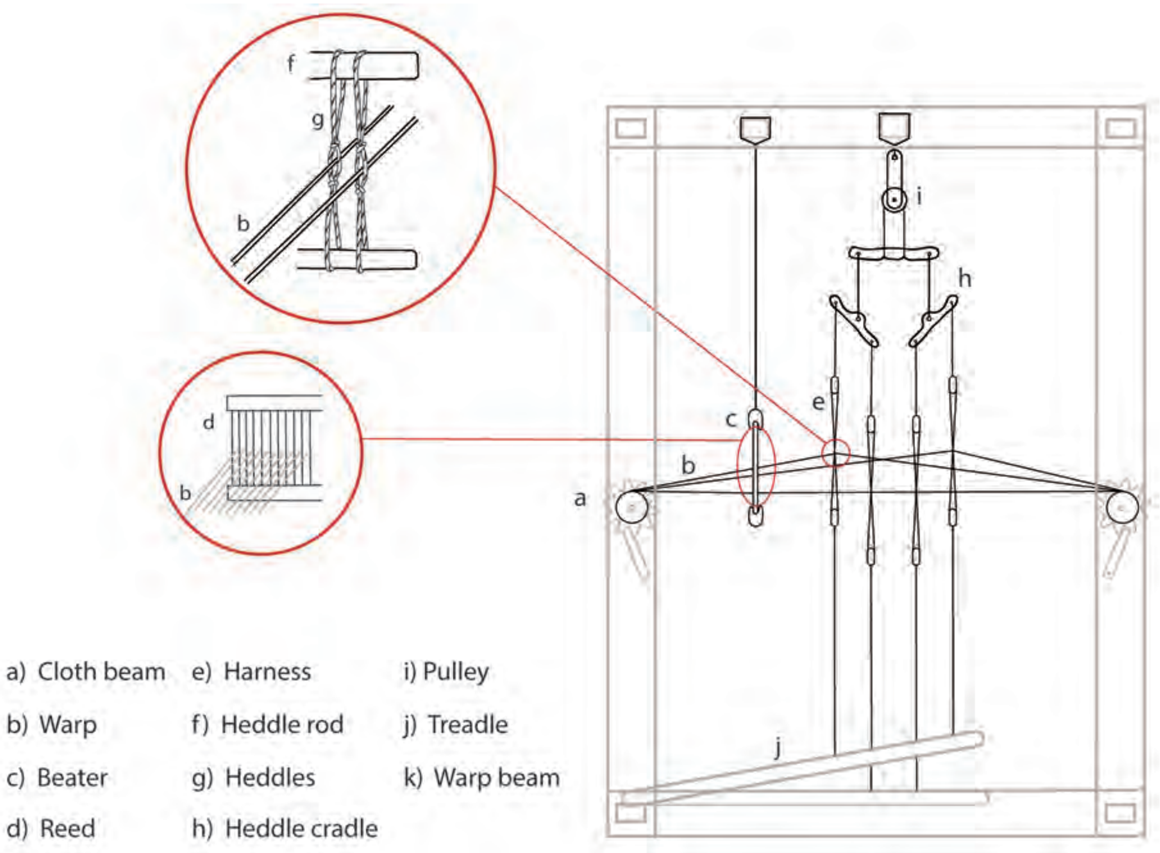

Fig. 5: Diagram of the mechanics of a horizontal treadle loom (Image: Gwendoline Pepper)

association is a 12th century account by Rashi of Troyes of a foot-powered loom, described in contrast to a loom controlled by the hands and used by women (Munro 2003, 194; Øye 2016, 2). There are records of women operating independently as weavers in the late Middle Ages (Salzman 1923, 217; Kowaleski & Bennett 1989, 476-477) and the proportion of female weavers seems to have been higher in rural areas of England (Goldberg 1992, 29). However, it seems that the most common way in which women participated within medieval weaving guilds was as the wives, daughters or widows of male weavers and they were rarely awarded the same status and privileges as their male counterparts (Kowaleski & Bennett 1989, 476-478; Goldberg 1992, 48). In this way, the roles women played in weaving guilds were largely dictated by their relationships to male guild members. That does not mean there was no autonomy to be gained by female weavers during this time period. In a survey of female occupations in late medieval Yorkshire, Goldberg found a significant number of women occupied independently as weavers, although their relationship to guilds is uncertain, and the proportion of weaving households that were headed by women was in the minority, particularly in urban centres (Goldberg 1992, 9-18). There is also European evidence of some women occupying higher ranking roles in textile production, including the esteemed role of draper in late medieval Leiden (Netherlands), although interestingly there is no evidence of female weavers or fullers in the city during this time period (Howell 1988, 71-72). There were also three women's guilds in Cologne (Germany): the yarn makers, gold spinners, and silk makers in which women held the role of mistress in their own right (Howell 1988, 124). Likewise, there were at least five such guilds in medieval Rouen, and seven in Paris (France) primarily focused on luxury textiles or linen (Kowaleski & Bennet 1989, 481). Despite this, there were still harsh restrictions on women's involvement in many other male-run guilds in Cologne, including the wool weaver's guild (Howell 1988, 134).

Essentially, while there are multiple examples of enterprising women making space for themselves in the late medieval textile industry, there is also ample evidence of dominant male-run guilds placing restrictions on women's roles within the guild structure. More to the point, while women continued to weave in late medieval England, and in fact played an important role even within the guild structure, they were no longer the main organisers of cloth production, as they seem to have been during the early Middle Ages. Furthermore, there was no parallel English formation of female-run textile guilds, even in London (Kowaleski and Bennet 1989, 485). The crucial activities of spinning and fibre preparation remained the domain of women, either as side work, or a sole occupation, but the work was not particularly lucrative (Goldberg 1992, 47). It seems to be because of these economic factors that past researchers such as Salzman treated female involvement in textile production as a mere footnote, at best, or assumed that female dominated activities such as spinning involved less skill, at worst (Stabel 2014, 52; Salzman 1923, 215). Despite the work of many researchers challenging these assumptions, this way of thinking left its own scars on the subject of medieval textile production, and the association of low status work with low skilled work can at times be observed even in research which has sought to illuminate the importance of female economic contributions during the Middle Ages (Karras 2004, 95; Howell 1988, 76).

Despite its relatively low status during the later Middle Ages, the activity of spinning yarn is an important aspect of medieval textile production. A competent spinner must possess the skill and understanding of raw materials required to spin strong yarn that will not easily fray and break during the weaving process. Therefore, the importance of skilled spinning should not be underestimated. The distinction between the tasks of weaving and spinning due to craft specialisation is important to consider when discussing transitions in textile processing. In the Anglo-Saxon period, the weaver and spinner would likely be the same person; she would understand what sort of yarn was required for the cloth she would weave, and would know how to produce this yarn. The evidence for specialisation at Coppergate reflects the development of the early household workshops that provided a foundation for guild organisation and gradual separation of these tasks. The archaeological evidence from Coppergate also demonstrates the link between different styles of loom and different approaches to textile production, which further indicates that the introduction of the horizontal treadle loom, and by inference the efficiency of this loom, was a key factor in the evolution of the medieval English cloth industry.

Methodology

This experimental programme had three main aims:

1. To better understand how the time invested by medieval weavers would have been impacted by the introduction of a new style of loom circa 1000 CE by determining the difference in time it takes to weave fabric on the warp-weighted loom and the horizontal treadle loom.

2. To record experiential observations over the course of the experiment, including ease of weaving on each loom, and any physical impact the weaving process has on the weaver's body.
3. To observe any physical differences between the cloth samples resulting from the process of weaving on each loom, including variations in the final dimensions and/or thread count of the cloth.

Two out of the three looms from this transitional period in medieval English cloth production were selected for comparison, as they: 1) represent the two extremes of time and gender division in weaving; 2) are most frequently compared by scholars discussing this transition; and 3) have been subject to previous time estimates.

The following parameters were established to eliminate as many variables as possible and to allow for a more accurate comparison of the differences between the looms:
1) The cloth produced in this process was not intended to be an exact replica of any specific medieval cloth fragment as a comparison of time was the primary concern;
2) The cloth to be woven was to be set up to the same width, length, weave structure and thread count on each loom; and
3) In recording the time it took to set up and weave on each loom, the process was broken down into comparable steps, wherever possible, and timed with a stopwatch. The actual weaving was conducted with an hour-long timer, and the quantity of cloth woven each hour was measured in centimetres.

It was decided not to correct any errors in threading or weaving unless it would ultimately affect the mechanics of the process. This was because the primary focus of this experiment was the evaluation of production time rather than producing a perfect piece of cloth. Therefore, a broken thread was to be fixed because too many broken threads would result in an inability to weave the cloth. However, threads threaded in the wrong order were to be left in place, as long as they did not interfere with the changing of the shed. This decision was also supported by evidence of threading errors found in surviving medieval cloth fragments (Pritchard 1984, 55; Walton 1989, 352).

Equipment

The warp-weighted loom and warping frame were constructed several years ago by Penelope Walton Rogers, who also commissioned the clay loom weights. The weights are all of consistent size and weight but are not specific replicas of an archaeological find. Since the key goal was to compare the basic mechanics of this loom, rather than observing differences in potential variations of the warp-weighted loom, this was not of particular concern. In order to more closely replicate the Anglo-Saxon method of weaving, a double-ended pin beater was fashioned from a piece of wooden doweling. This experiment did not have the resources to construct looms from scratch, therefore, the horizontal treadle loom used in this experiment was a countermarche loom loaned by Ruth Gilbert along with a warping board, shuttle and other pieces of equipment necessary for the setup and weaving process. The loom is not a replica of a medieval loom but matched the vital mechanics of the medieval horizontal treadle loom, namely, treadle operated harnesses, a suspended beater and reed, and a front cloth beam and back warp beam. These two looms permitted a reasonable comparison of these two loom types.

Rulers, a measuring tape, tapestry needles, and glass-headed pins were also used during the setup, weaving, and recording of the pieces of cloth. Cotton seine twine was used during various stages of setup. This is a material that would not have been used during the Middle Ages, but was the most economically viable option available. A phone with a stopwatch and timer app was used to record the times.

Rationale for the dimensions, fibre and structure of the cloth

In order to ensure the experiment reflected weaving practices that could have occurred on both looms, the cloth needed to be of a structure and fibre that would have been commonly produced in both early and late medieval England. This presented a problem of continuity with wool cloth, which was usually woven in 2/2 twill during the Anglo Saxon period but by the tenth century was more commonly woven in 2/1 twill (Walton Rogers 2007, 73). This practice continued into the 13th century when 2/1 appears to have become the most common structure for wool cloth (Crowfoot et al. 2006, 27). It has been suggested that, in England, the switch to 2/1 twill is connected to the use of the two-beam vertical loom, as the evidence for the use of this loom is contemporary with the rise in production of this type of cloth (Walton Rogers 2001, 166). It should be noted that the origins of this trend in cloth structure has been the subject of some debate. Hoffmann (1974, 202-04) has argued that the warp-weighted loom is not ideally suited to the weaving of a 2/1 cloth structure and considered the production of 2/1 twills to have been something of a mystery. There has been a suggested association with the use of the horizontal treadle loom (Øye 2016, 10), but Crowfoot et al. argue that the horizontal treadle loom is also ill-suited for weaving an unbalanced structure (Crowfoot et al. 2006, 27). It is important to note that neither Crowfoot et al. nor Hoffmann have claimed that it would be impossible to weave a 2/1 twill on a warp-weighted loom or a horizontal treadle loom. It certainly is possible on both looms. They have simply pointed out that an unbalanced twill is not ideally suited to these looms since both function optimally with a balanced weave and therefore the 2/1 twill is not a logical structure to have emerged from the use of these looms. Comparing the process of weaving a 2/1 twill across different types of loom is an interesting potential experiment. However, it is beyond the scope of this project and would have distracted from the main research question of efficiency.

Linen cloth, in contrast to wool, seemed to change little in connection with the introduction of new weaving technology to medieval England. While a small number of linen twills have been found from the early Anglo-Saxon period (Walton Rogers 2007, 70), and from later Anglo-Scandinavian Coppergate, York (Walton 1989, 354), the overall trend was for linen to be woven in a tabby with z-twisted yarn (Walton Rogers 2014, 268). Evidence from London indicates that this continued into the high Middle Ages (Crowfoot et al. 2006, 80). Linen tabby cloth was therefore an ideal control test for the comparison of the two looms, as it eliminated an additional variable of changing cloth structure and, given the broad date range during which this type of cloth was produced, linen tabby could certainly have been woven on both the warp-weighted loom and the horizontal treadle loom. The linen thread for this experiment was ordered from Borg's Vävgarner, a company based in southern Sweden. This yarn is z spun, single ply and the gauge of thread was 28/1, approximately 0.4 mm to 0.5 mm in diameter. This yarn weight falls within the range of thread diameters from linen textiles found in York and London (Pritchard 1984, 64; Walton 1989, 432-443).

Thread count

Thread counts varied broadly throughout the medieval period, depending on the quality and purpose of the cloth. Linen tabby weaves, the primary concern for this experiment, tended towards slightly finer thread counts than their wool counterparts, ranging from 8/7 to 44/22 during the Early Anglo-Saxon period.

The majority of Early Anglo-Saxon linen fragments fall between 10/10 and 24/24 threads per cm (Walton Rogers 2007, 67), which is a broad range. Linen fragments from urban York and London dating from the tenth to the 12th centuries are closer to 10 to 20 threads per cm (Walton 1989, 439-443; Crowfoot et al. 2006, 80). However, while some of the fragments are perfectly balanced, there is an overall tendency for slightly higher warp counts than weft counts.

A warp and weft count of approximately 14 threads per centimetre was chosen for this experiment as it fell within the range of warp thread counts from linen textiles throughout the Middle Ages and was most likely to produce a balanced cloth based on the gauge of the linen thread.

Width

It was important for this experiment to approximate the medieval experience of weaving linen yardage by setting up a width of cloth that could be reasonably woven on both looms. However, interpreting the weaving width of cloth in medieval England is a somewhat daunting task. The association of the warp-weighted loom with relatively wide cloth widths as well as the possibility of narrower widths being woven has already been discussed. Cloth widths in the transition from the warp-weighted loom to the horizontal treadle loom are difficult to determine, although they likely started out fairly narrow. Early depictions of horizontal treadle looms (fig. 2) suggest fairly narrow weaving widths. Archaeological evidence for loom widths is scarce, but in tracing the origin of the horizontal treadle loom, Carroll discusses some surviving reeds of probable "Coptic" origin which give an idea of the maximum fabric widths which could be produced on early horizontal looms in Egypt. The three examples measure 27, 29 and 26 inches wide (Carroll 1985, 169), or approximately 68.5 cm, 78.5 cm and 66 cm, respectively. As part of her study of the way cloth widths might influence the cut and construction of garments, Burnham estimated an even narrower cloth width, asserting that the tunic of St Louis, dated to the 13th century was constructed from fabric 22 inches, or 56 cm wide. It should be noted that Burnham was unable to make a "proper examination" (Burnham 1973, 12) and so this measurement should be considered with caution.

By the late 12th century, regulations on the width of cloth for import and export in England began to appear and these are far wider than the measurements provided by Burnham and Carroll. A royal proclamation from 1196 stated that cloth woven should be two ells in width (Walton 1991, 328). Unfortunately, it is difficult to interpret the equivalent modern-day measurement, as the study of early medieval measurements is a field rich of ambiguity and disagreement. According to Prior, the ell was equivalent to the yard (which was originally a cloth measure) from the Norman conquest up to the reign of Richard II (Prior 1924, 142). However, we cannot be sure that the medieval yard was the same as the modern yard, or even that it remained consistent throughout the medieval period. Fernie cited evidence for the English yard measuring 91.5 cm. He also referenced William of Malmesbury, who described the length of a yard as equivalent to the king's own arm (the king in question being Henry I) but argued that this may have been more of a symbolic statement than a literal one and could actually imply that the yard measured from the king's nose to finger tips, or his arms would have been peculiarly long (Fernie 1985, 252). Gelsinger, working from the same source, stated that an ell was equivalent to the forearm of the king, and that two ells made a yard (Gelsinger 1981, 128), which suggests a similar measurement for the yard, but implies a very short ell in contrast. Around 1100, the early Icelandic ell was apparently replaced by a shorter ell, which equalled the length of the English ell (Hayeur Smith 2014, 36). Dennis et al. suggest in their 1980 translation of the Grágás (early Icelandic laws) that the Icelandic ell was initially 49 cm but was replaced by an ell of 54 cm to 57 cm (Dennis et. al. 1980, 244), which seems to contradict the suggestion that the ell was shortened to match English standards. It is a little unclear how these measurements were determined but, if nothing else, this further emphasises the variability of this measurement. From these sources alone, the width of the English yard/ell potentially measured anywhere from 54 cm to 91.5 cm, suggesting that in England during the high Middle Ages, a two ell width of cloth might have measured anywhere from 104 cm to 183 cm. Regardless, this range of measurements does suggest a gradual widening of woven cloth during the later Middle Ages. That being said, there are late medieval records of fines paid in order to continue weaving a narrower width (Walton 1991, 328). This makes sense, as transitioning to produce wider cloth would require investing in a wider loom (Salzman 1923, 218). Essentially, while the set standard cloth width by the 12th century was 2 ells, this does not necessarily reflect what all professional weavers produced. It is therefore possible for medieval English cloth to have been produced in a variety of widths from as narrow as 56 cm to upwards of 180 cm, and these higher widths would primarily be limited individually by the width of loom in use. Bearing in mind the potential range of fabric widths throughout the Middle Ages, it was decided early on that a narrower width within this range would be preferable for this experiment, as the horizontal loom to be used would not be able to accommodate the same cloth width as the warp-weighted loom, and time constraints needed to be taken into consideration. Ultimately a starting width of 66 cm was selected for this experiment as this was one of the middling measurements of the previously discussed Coptic reeds and seemed both wide enough to produce a useful piece of cloth, yet narrow enough that the cloth could fit both loom width and be woven easily by one person.

Length

A 2 m warp length was chosen as this guaranteed multiple hours of weaving on both looms, yet was short enough to be woven within the three month time frame of this experiment.

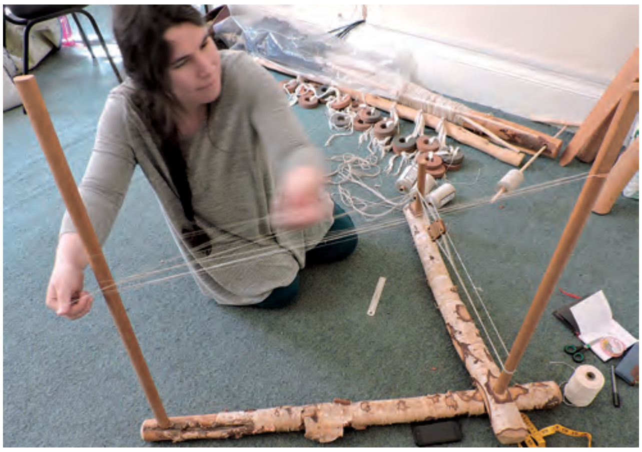

Fig. 6: Warp for the warp-weighted loom being wound on a warping frame (Image: Ellie March)

Fig. 7: Detail of the tablet-woven starting band showing the easy division of alternating threads (Image: Gwendoline Pepper)

Fig. 8: Lashing the warp to the warp beam (Image: Ellie March)

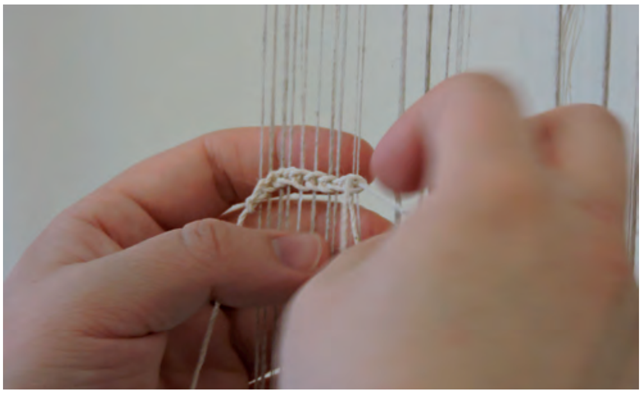

Fig. 9: Chaining the spacing cord around the warp threads (Image: Janet Finlay)

Process

Warp-weighted loom

The warp was made with a tablet woven starting band on a warping frame (fig. 6) to ensure consistent spacing of the warp threads and prevent tangling. This method also allowed for easy division of alternating threads (fig. 7). The separated thread bundles were tied in slip knots to prevent tangling while the warp was lashed to a dowel, which was then lashed to the warping beam (fig. 8). The divided warp was arranged with half of the alternating warp threads placed in front of the warp beam, while the remaining were left

Fig. 10: Tying the heddles around alternating threads (Image: Gwendoline Pepper)

Fig. 11: Arranging the weft into place with a double-ended pin beater (Image: Penelope Walton Rogers)

Fig. 12: Beating the weft with a weaving sword (Image: Penelope Walton Rogers)

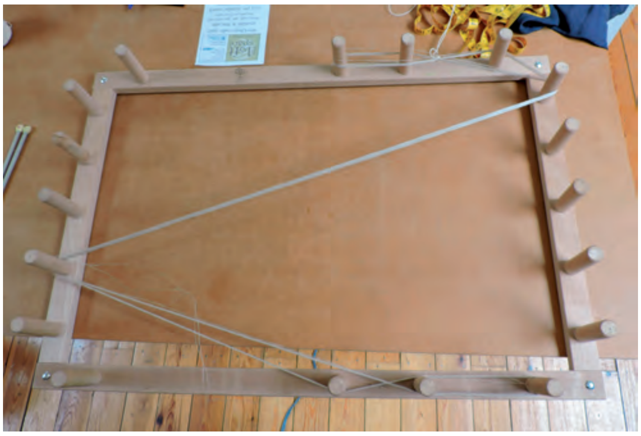

Fig. 13: The warp for the horizontal treadle loom wound on a warping board (Image: Gwendoline Pepper)

to hang behind. To keep the spacing of the threads consistent, a cord was then chained across the warp, looping around every three threads (fig. 9) and shifted to the bottom of the loom. The heddles were tied around every back thread, spaced with a rod, which was placed in the shed and tied into place against the loom uprights (fig.10). Before weaving, the weft was wound on the end of a wooden dowel to keep it from tangling and was then inserted with each change of the shed and arranged into place using a double-ended pin beater (fig. 11). At first, the weft was beaten with the weaving sword (fig. 12) every shed change but after about five hours of weaving, this switched to beating every other shed change and at this point the pin beater was also used to help separate the shed. When running out of room to weave, the cloth was rolled on to the cloth beam, the weights removed and

Fig. 14: The warp separated by lease sticks, attached to the warp beam, and spaced in the raddle ready for winding (Image: Gwendoline Pepper)

Fig. 15: Winding the warp on the horizontal treadle loom (Image: Ruth Gilbert)

Fig. 16: Threading the heddles on the horizontal treadle loom (Image: Ruth Gilbert)

Fig. 17: Beginning the weaving on the horizontal treadle loom with the starting band just visible (Image: Gwendoline Pepper)

tied lower on the warp. This was done twice before the weaving was finished.

Horizontal treadle loom

The warp was wound on a warping board, crossing threads to keep the yarn organised (fig 13). The cross-end of the warp was attached to the back beam after lease sticks were inserted into the cross and the warp was then spaced across the raddle (fig. 14). The warp was then wound on to the back beam while under tension (fig. 15) and warp sticks were inserted at intervals to keep the warp winding evenly. Each thread was fed through a string heddle (fig. 16). After this, the thread was pulled through the reed in a process called sleying. Three threads per dent ensured the desired thread spacing. After this, the warp was lashed on to the front beam, tensioned evenly, and a short starting band was woven to establish thread spacing. The cloth was woven using a boat shuttle, beating the weft after every shed change (fig. 17). The warp was wound off the warp beam and the cloth was wound on to the front beam as the weaving progressed, which, due to the speed of weaving, was done multiple times per hour.

Cloth finishing

The ends of both samples were finished with a simple whipstitch to keep the cloth from unravelling. It was then washed to relax the threads. The appearance, thread counts and dimensions of the cloth produced were recorded before and after washing.

Results and observations

The results of this experiment (table 1) confirm that it is possible for a weaver to produce cloth significantly faster on the horizontal treadle loom than on the warp-weighted loom. The total time for cloth production on the warp-weighted loom was 37 hours and 1 minute. The total time for cloth production on the horizontal treadle loom was 19 hours and 27 minutes. Therefore, in terms of total production time, this means that the weaver was able to produce cloth with the horizontal treadle loom at approximately 1.9x the rate of production on the warp-weighted loom. That being said, the total setup times for both looms were nearly identical, and threading the horizontal treadle loom took more than twice as long compared to the warp-weighted loom, which demonstrates that the newer style of loom is not actually more efficient at every stage of textile production.

The experiential aspect

A significant difference between the two looms, which became immediately apparent during the experiment, was the skill and experience required. The

	Warp weighted loom	**Horizontal treadle loom**
Time spent making warp	4 hours 16 mins	2 hours 46 mins
Time spent putting warp on the loom	5 hours 38 mins	1 hour 04 mins
Time spent threading loom/spacing threads	5 hours 06 mins	11 hours 14 mins
Total time setting up loom for weaving	**15 hours 1 mins**	**15 hours 04 mins**
Average # of cm woven/hour	5.8 cm	29.8 cm
Highest # of cm woven/hour	8.9 cm	42.5 cm
Least # of cm woven/hour	2.3 cm	18.7 cm
Total time spent weaving	**22 hours**	**4 hours 23 mins**
Total time spent making cloth	**37 hours 1 mins (37.02)**	**19 hours 27 mins (19.46)**

Table 1: Timed results from each stage of weaving a linen tabby fabric, 66 cm width on a 2 m long warp made of z twisted yarn (z/z) with a 0.4 cm to 0.5 cm thread diameter, and a thread count of 14 threads/cm in each direction (14/14)

warp-weighted loom, being simpler in construction, required more skill and care in order to weave consistent cloth. Essentially, simpler equipment results in more work for the weaver. At the time of the experiment, the weaver had six years of experience weaving cloth on multiple types of loom.

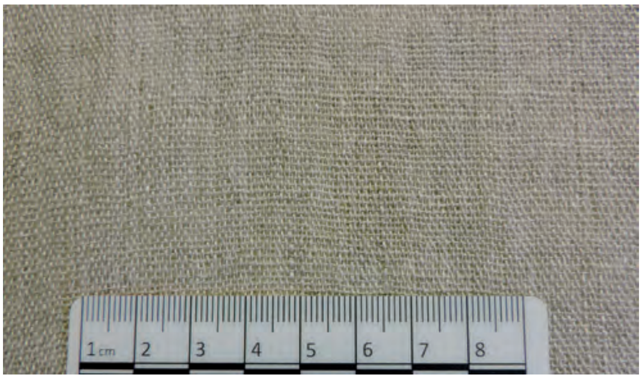
Fig. 18: Detail of the cloth woven on the horizontal treadle loom showing the even spacing of weft threads (Image: Gwendoline Pepper)

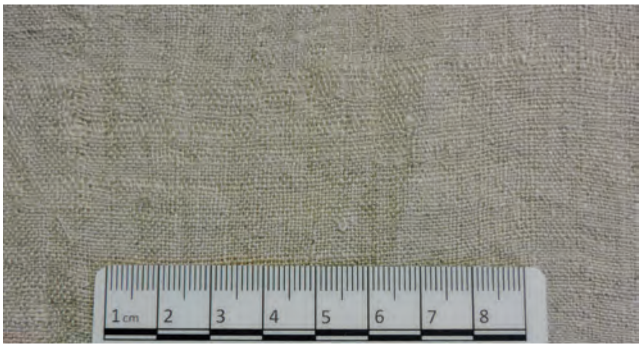
Fig. 19: Detail of the cloth woven on the warp-weighted loom showing minor inconsistencies in weft spacing (Image: Gwendoline Pepper)

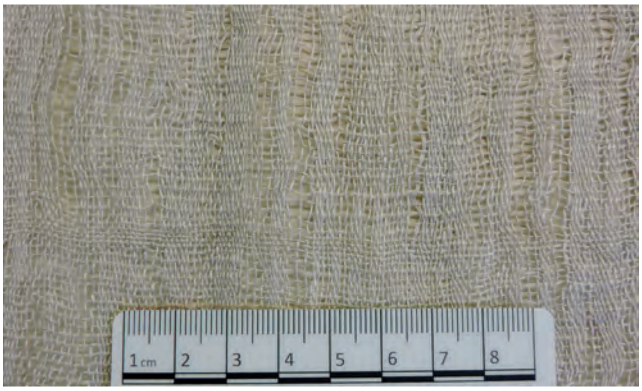
Fig. 20: Detail of the cloth woven on the warp-weighted loom showing more dramatic inconsistencies in weft spacing (Image: Gwendoline Pepper)

Therefore, their skill level was such that they could weave a reasonably consistent piece of fabric on the horizontal treadle loom, where the reed ensured consistent spacing of warp threads, while the built-in beater (fig. 5) made it fairly easy to space the weft evenly at a 90º angle to the warp threads (fig. 18). In contrast, the weaver struggled at times to keep the spacing of the weft consistent and to beat the weft evenly from edge to edge while working with the warp-weighted loom (fig. 19). The level of care required by the warp-weighted loom is an important factor in the time it takes to weave, as can be seen in sections of cloth where more centimetres were woven per hour, but consistency was sacrificed (fig. 20). Another aspect of this inconsistency, which should be noted, is that the weaver had more experience weaving with wool than with the linen used in this experiment, particularly on the warp-weighted loom. Linen is less forgiving than wool due to its lack of elasticity. Should this experiment be repeated, it would be worthwhile to weave a practice cloth on each loom that would not be timed. This recommendation for practice time before measuring is a precedent set in the experimental practice for the Centre for Textile Research's *Tools and Textiles - Texts and Contexts* project (Mårtensson et al. 2006, 3). There was not enough time to run a practice session within the schedule of this project; in future, this would help ensure that the weaver was carrying out the experiments with an established level of comfort on the specific looms to be used.

Aside from skill and experience, stress may have also been a factor, as the days which produced particularly inconsistent lengths of cloth were usually days during which the weaver was feeling distracted or pressured. Interestingly, during this experiment the same feelings of distraction and pressure did not appear to have the same impact on the cloth woven on the horizontal treadle loom as there was very little variation in the thread density of the finished cloth. Since archaeology is a material study of human activity, it is worth considering how the mental state of a craftsperson may be reflected in a finished object. While the impact of emotions on craft practice may be impossible to interpret from the archaeological record alone, it can be argued that this is still a factor worthy of reflection. For example, in relation to the weaving process, the horizontal treadle loom acts as an intermediary between weaver and cloth, which is a useful role for a loom used to weave large quantities of cloth commercially, and further emphasises that an Anglo-Saxon weaver using a warp-weighted loom would likely have needed to exercise more control, both of themselves, and of the threads throughout the weaving process.

The previously mentioned difference in the ratio of setup time to weaving time between the two looms resulted in another interesting observation related to the experience of weaving: it is commonly said by modern hand-weavers that setting up a loom takes longer than the weaving process. This experiment demonstrates the truth of this in relation to the horizontal treadle loom, while demonstrating that, in contrast, weaving using the warp-weighted loom takes significantly longer than setting up the warp. Over the course of the experiment, this discrepancy resulted in a difference in the levels of satisfaction for the weaver while weaving on each loom: after spending so long setting up the warp, weaving on the horizontal treadle loom felt as though it was over nearly as quickly as it began, and, as a result, the weaver felt more focused on finishing the cloth, than being immersed in the experience of weaving.

In contrast, the weaving stage on the warp-weighted loom dominated their experience because it took more time than setting up the warp. In addition, the weaver was more aware of the full sensory experience of the weaving process, from the clacking of the loom weights, to the feeling of the linen thread between the fingers as the shed was changed. This difference is interesting to consider when thinking about how an early medieval weaver may have experienced the process of making cloth in comparison to a late-medieval weaver. Extrapolating further, it is possible that the experienced early medieval weaver may have had a calmer, more immersive sensory experience during the cloth weaving process than the late medieval weaver, who may have been pushed into a higher-stress production mindset due to the increased efficiency of weaving on the horizontal treadle loom. That being said, it is possible to set up longer warp lengths on the horizontal treadle loom in contrast to the warp-weighted loom (Øye 2016, 6), which is a factor not accounted for in this experiment. It would be worth running a series of tests weaving different lengths of warp on the horizontal treadle loom, in order to determine where the equalisation point might be between setting up the length of warp and weaving. It is likely that while a longer warp takes more time to weave, it also takes more time to set up. Figuring out where these lengths of time intersect would contribute to an understanding of how weaving to maximise cloth production may have been approached in a workshop setting during the late Middle Ages.

Analysis

This experiment has allowed for an assessment of the impact technology has on the time it takes to weave cloth, but it has also illuminated how complicated this comparison really is. While one may weave cloth significantly faster on the horizontal treadle loom than the warp-weighted loom, not every stage of the process is more efficient; the setup times were nearly equal, but the threading stage took longer on the purportedly more efficient loom. In comparing the total times, the horizontal treadle loom was only approximately twice as fast as the warp-weighted loom. This highlights the need to consider the entire weaving process when discussing the horizontal treadle loom as a medieval technological innovation.

Technology, skill and gender

This experiment has demonstrated that weaving consistent cloth on the warp-weighted loom requires more skill than weaving equivalent cloth on the horizontal treadle loom. The issue of skill is significant, as the skill of the weaver can be overlooked when discussing technological innovation. This omission is compounded by the fact that there has been an unfortunate trend in writing on late medieval weaving to describe the roles which women continued to occupy in textile production as unskilled, without any means of accurately quantifying the skill involved in such tasks.

The horizontal treadle loom's incorporation of a reed and built-in beater allowed for functional cloth to be woven with considerably less skill than the warp-weighted loom. This does not mean that the operation of the horizontal treadle loom is unskilled work, but the level of automation provided by this new type of loom meant that the male weaver in late medieval England would have been able to produce cloth more quickly, with less care than was previously the case. This mild de-skilling of weaving associated with the introduction of the horizontal treadle loom is another important factor in the growth of the English textile industry during the high to late Middle Ages. It should not be considered a coincidence that this de-skilling of labour preceded male clothiers/drapers/weavers seizing control of textile production.

It is interesting that the introduction of a machine which allowed for a reduction in the necessary skill to produce serviceable cloth is so strongly connected to increased craft specialisation. One might expect a higher level of skill to have been involved in a specialised trade. However, the fact that a weaver could specialise in weaving as a trade, and focus his time on a single task under the overall organisation of clothiers and/or drapers (Karras 2004, 97), rather than working on multiple stages of textile production ,would also have a significant impact on the quantity of cloth produced. In contrast, Anglo-Saxon textile production did not involve this same division of labour in terms of textile production, meaning it would have been common for an Anglo-Saxon weaver to develop skills beyond weaving alone.

One factor which likely contributes to the connection of the horizontal treadle loom with the specialisation of labour is the complication of acquiring the equipment itself. Specialist knowledge would be required to construct such a machine, making it more likely that a weaver would need to import or commission the construction of a loom. The horizontal loom would also take up more space, which not every household would be willing or able to accommodate. This was certainly the case in Early Modern Iceland when the horizontal treadle loom was introduced, and alterations to both loom and house needed to be made to accommodate this new weaving equipment (Hoffmann 1974, 225-226). It is likely that the same space considerations would have impacted the medieval weaver. The expenses of owning a horizontal treadle loom would have stretched beyond simply acquiring one: there are recorded fees for owning and operating a loom in late medieval England, such as the payment of five shillings per year per loom to the town authorities required in 13th century Winchester (Salzman 1923, 218-219). Therefore, it is not just the efficiency or the de-skilling effects of this loom which encouraged specialisation, but the nature of the machine, as both a spatial and financial investment, which may have made specialisation a necessity.

In order to interrogate why this specialisation is connected primarily with men, one must focus on who controlled textile production over time. The varied ways in which women made vital contributions to cloth production in England and in Europe in the late Middle Ages has been discussed. It is clear however, that despite these contributions, female textile workers were frequently overlooked or treated as subordinate by the English guild system, and it is clear that while women still participated and played arguably crucial roles in textile production, they no longer controlled cloth production as they had during the early Middle Ages. This is reflected by restrictions such as one at Norwich, which alleged women did not have the strength to weave proper worsted cloth (Salzman 1923, 217). The experimental loom comparison demonstrates, however, that this assertion is false. The weaver in this experiment can say from experience that beating the weft vertically with a weaving sword while working at the warp-weighted loom takes at least as much strength as does beating the weft horizontally with a beater bar on the horizontal treadle loom, and a good deal more endurance due to the constant upward arm movements. Such written evidence indicates a bias against female labour in some primary medieval sources, which is likely indicative of broader attitudes during this time.

Exactly why this gender switch in weaving came to be is complicated and merits further research. The supremacy of male weavers in guilds contrasts strongly with the role of women as key organisers of textile production during the Anglo-Saxon period. However, this displacement of women as organisers of textile production appears to be congruent with an overall reduction of female autonomy during the Middle Ages. The status of women in medieval British society appears to have been negatively impacted by the Norman conquest of 1066, as an obsession with land-tenure influenced attitudes towards marriage and rights of inheritance, further infringing women's freedoms (Clark & Williams 1984, 149). From this point on, a woman was unlikely to own land, had little freedom of choice in marriage, and, upon marriage, her finances were under her husband's control (Clark & Williams 1984, 149). Additionally, in contrast to the relative equality experienced by both male and female converts to Christianity during the Anglo-Saxon period (Fell 1989, 109), a complicated relationship developed between the Christian church and women post-1066. Despite a belief in the equality of all souls, anti-female attitudes seem to have increased, spurred on by late 11th century Gregorian reforms (Clark & Williams 1984, 152). However, this is not a clear-cut issue. Canon law, for example, emphasised the idea of spiritual love, leading to a requirement by canon lawyers of full consent from both parties in the event of marriage, while simultaneously alleging the inferiority of women (Clark & Williams 1984, 153-54). Based on this, one cannot attribute this reduction in women's status solely to Christianity, but an increasing adherence to canon law after the Norman Conquest may have played a significant role.

The observations from this experiment highlight that, for centuries, the type of weaving that has been typically defined as "women's work" was a highly skilled and time-consuming task. The adoption of new specialised technology led to an increase in weaving speed and a reduction in the skill required to produce cloth. At the same time weaving as a trade became associated with male craftsmen.

Ultimately, the adoption of new technology and reduced weaving time appear to be key factors in the process of weaving becoming a male-dominated trade, but these factors should not be taken for granted as a complete explanation of why men came to inhabit the role of weaver. The fact that male weavers are so strongly connected to the growth of the English cloth industry despite the continued involvement of women, highlights a key issue in the discussion of weaving and gender in the medieval period. Boulding (1976, 96) writes, "Woman's production is normally noticed by statisticians only when it leaves the home. Man's production is more apt to be noticed whether it leaves the home or not." This illustrates how our understanding of the status of female weavers throughout history is at least partially coloured by scholarly biases.

The academic diminishment of the role of medieval women as administrators and organisers during the later Middle Ages is a recognised problem in the field of archaeology (Gilchrist 1997, 44). This has been particularly demonstrated in the way that the role of women in late medieval production has been discussed in the past. Øye has called attention to a tendency amongst historians to dismiss the likely crucial role that wives and daughters would have played in household-based production during the birth of the guild systems (Øye 2016, 12), which underscores Boulding's argument. Therefore, the study of gender and weaving in medieval England not only involves the examination of shifting attitudes towards women during the Middle Ages, but also requires the acknowledgement of a foundational academic bias that, despite being challenged by many contemporary scholars, can still influence the study of medieval female labour. Technology-driven production organised by a male workforce has previously taken precedence over time (and skill) intensive female-organised labour in the study of the medieval English cloth industry. If we are truly to understand the changing role of time and skill in connection to medieval weaving, this topic must be examined through a feminist lens.

Conclusion

Examining time in relation to the processes of textile production is significant to the study of medieval craft practices, as it allows for a better understanding of how labour may have been organised, the impact of new technology on craft production, and, in a broader sense, how different types of labour were regarded at various points during the Middle Ages.

This experiment has focused on loom type as a factor affecting weaving time. A controlled methodology was achieved by using the same weaver, cloth width, and thread density on two different looms, but the results cannot accurately reflect specific early and late medieval cloth production times. This experiment has instead allowed for the isolation of technology as a factor in weaving speed, which has clearly emphasised that other variables such as skill and access to tools, would have had an equally important impact on production time and the organisation of textile manufacture during the Middle Ages. The issue of skill in particular highlights problems with the way in which gendered labour has historically been regarded. Further experimentation can address differences in modes of production, factoring in other variables and testing variations in equipment. It would be worthwhile, for example, to build a horizontal treadle loom of the style depicted in medieval sources, keeping in mind what archaeological evidence is available. It is likely that advances in the design of this type of loom will have been made over time. Therefore, while the basic mechanics are close enough to the loom which was used for this experiment that the results are still relevant, it would be worthwhile to work with a custom-built loom in order to understand any differences in operation which may have been overlooked here. Regardless of these variables, however, it is arguable that the general impression of faster weaving on the horizontal treadle loom, and the key observations of difference in required skill level will likely remain unchanged.

The results of this experiment, when viewed in relation to historical context demonstrate some of the biases inherent in discussing gendered labour. The emergence of the role of "weaver" as a profession is the result of a number of factors, but this evolution of weaving as a male-organised trade appears to be strongly linked to the introduction of the horizontal treadle loom. The key observation from this experiment is that the skill necessary to produce cloth on the warp-weighted loom is far greater than that required by the newer horizontal treadle loom. Reframing the discussion of this technological transition as not just an increase in efficiency, but a moderate de-skilling and increased division of labour, will allow for a more nuanced discussion of gender roles and the medieval textile economy. Furthermore, this experiment has demonstrated the value of experimental archaeology as a tool for conducting a feminist analysis of medieval labour practices.

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Beatrix Nutz

Nets – Knots – Lace:

Early 16th century headdresses from East Tyrol

In memoriam Liselotte Zemmer-Plank

Abstract
In an excavation carried out in 1968 four headdresses dating from the early to first half of the 16th century were discovered in a crypt in the parish church of Lienz in East Tyrol (Austria). All four headdresses are remarkably well preserved and two of them reveal techniques that are surprising considering the early date. A hairnet with macramé knots and a coif adorned with bobbin lace most likely date before 1509 making them the earliest extant examples of macramé and bobbin lace to date. This paper gives an account of the finds and considers the implications these headdresses might have on the history of lace.

Key words: 16th century, headdress, netting, filet, macramé, bobbin lace, hairnet

The excavation
In the course of the restoration of the parish church of St Andrew in Lienz-Patriasdorf in 1968 the Tyrolean State Museum Ferdinandeum carried out extensive archaeological investigations for the clarification of historical questions (Zemmer-Plank 1974). The excavations revealed six tombs, two in the north and one in the south aisle, a crypt located in the western choir room, a crypt located in the presbytery and a crypt in the central axis of the nave in front of the crucifixion altar. The crypt in the central axis in front of the altar (crypt II) was the entombment of the Freiherr Michael von Wolkenstein-Rodenegg and his wife Barbara von Thun. This was clarified by a reference found in part III, section 3, caput XIII of Matthias Burglechner´s manuscript *Tirolischer Adler* of 1619 (Burglechner 1619, III/3/XIII, 889). Burglechner wrote: *…. in mitten der Kirchen vor dem Kreizaltar liegen Herr Michael Freiherr zu Wolkenstein, und sein Gemahl Frau Barbara von Thun mit dieser grabschrift „hie ligen begraben die wolgeporn herr michel freyherr zu wolgkenstain un sein gemachl frau barbara geborne freyn zu thun die an mittich des XXIX tag augusti im mdix und obbemelter freyherr an XV tag april und in mdxxiii jar gestor[b]en sein den got gnadig sein"* (in the middle of the church in front of the crucifixion altar rests Michael Freiherr zu Wolkenstein and his wife Barbara von Thun with this epitaph "Here rests the noble Freiherr Michael von Wolkenstein and his wife Barbara née Freiin zu Thun who died on Wednesday 29 August 1509 and aforementioned Freiherr on the 15th day of April in the year 1523 God have mercy." Freiherr was a title of nobility in the German-speaking areas of the Holy Roman Empire. It corresponds to baron in rank. The original distinction from barons was that a Freiherr's landed property was allodial instead of a fief (an allod is a land over which the owner can dispose freely). Freiin is the title of an unmarried daughter of a Freiherr.

Michael von Wolkenstein-Rodenegg and Barbara von Thun
Michael von Wolkenstein-Rodenegg came from an old Tyrolian family and was the grandson of the poet and composer Oswald von Wolkenstein. Michael was a Knight of the Golden Fleece and a particularly respected member of the Tyrolean government who served as *Landhofmeister* (Lord steward of a province – Ebers 1798, 480) at the court of Emperor Maximilian I. Michael von Wolkenstein

lived in the Hofburg in Innsbruck and had a high salary of 1000 flRh per year (flRh = Rhenish guilder. Latin: *florenus Rheni*). His accommodation included a kitchen, cellar and bath. As additional benefits in kind he could pick the fruit in the courtyard garden as much as he needed, received wood for three rooms and the kitchen stove, two deer every year and enjoyed the duty-free import of a number of oxen from Carinthia (Adler 1886, 384, footnote 1). A letter from 12 October 1502 to the regiment in Innsbruck (RI XIV, 4.1 n. 16988, in *Regesta Imperii Online*) proves how high Michael von Wolkenstein stood in the favour of the emperor. In it Wolkenstein´s debt of 300 guilders for pearls was erased. The reason was that Maximilian and his wife Bianca Maria Sforza had *„ain kint aus der Tauf gehebt und ir dieselben Perlen in das kindlpet geschenkt"* (RI XIV.4.1 n. 16988 in *Regesta Imperii Online*). They acted as godparents to a child, Regina Bianca, of Michael and his wife Barbara and the pearls were a baptism gift (Egg 1998, 155). Michael von Wolkenstein-Rodenegg was also involved in the completion of the Golden Roof in Innsbruck in the years 1495 to 1500. His coat of arms is carved on the back of a relief of one of the *Moriskentänzer* (Morris dancer). The fact that a simple Freiherr was allowed to place his coat of arms on a monument intended to display the Glory of the King and the House of Habsburg shows that Michael von Wolkenstein had proved his skills as financier and commissary on behalf of his king. In 1501 Maximilian I sold him the rule of Lienz that included Bruck Castle, the city of Lienz, the office and district court Lienz with the associated courts and offices Kals and Virgen with Defreggen for the price of 22.000 flRh (RI XIV, 3.1 n. 12327, in *Regesta Imperii Online)*.

Barbara von Thun belonged to the court of the queen Bianca Maria Sforza. Barbara is mentioned for the first time on 6 July 1494 as a member of the *Frauenzimmer* and on 18 August 1495 named as lady-in-waiting. At courts of the 15th century the entire royal household of a noble lady and her apartments was referred to as *Frauenzimmer* (*frawenzymer*). By order of Emperor Maximilian she was raised in rank as her family was ennobled to *Reichspanierherren* (= Freiherren) in 1495 (RI XIV, 1 n. 3641, in *Regesta Imperii Online*). Barbara von Thun married Michael von Wolkenstein-Rodenegg on 29 March 1497. The wedding took place in Innsbruck in the presence of Maximilian I, but in the absence of the queen, who resided in Worms at the time. Barbara remained a member of the *Frauenzimmer* and probably only left when her husband became *Landhofmeister* in Innsbruck in 1500, officially the highest office of the Austrian

Fig. 1: Effigies of Michael von Wolkenstein-Rodenegg and his wife Barbara von Thun. Table tomb in St Andrew, Lienz, East Tyrol (© BDA. Image: Bettina Neubauer, 2012)

countries in the West. When Michael von Wolkenstein acquired the rule of Lienz, the couple moved to East Tyrol and resided at Bruck Castle. Barbara fell severely ill after the birth of her seventh child in 1509 and died the same year on 29 August at the age of 26 years (Korotin 2016, 203–205).

When Michael von Wolkenstein-Rodenegg died on 15 April 1523 in Innsbruck, they transferred him to Lienz and buried him beside Barbara von Thun. During his lifetime, he had already commissioned a magnificent table-tomb in the parish church of Lienz with effigies of himself and his wife (Mannhart 1958, 54–55) (fig. 1). The rule of Lienz belonged to the house of Wolkenstein-Rodenegg till 1642 when the family went bankrupt. This resulted in the transfer of the rule of Lienz and thus also Bruck Castle to the Tyrolean Prince Archduke Ferdinand Karl.

The crypt – construction and contents

At a distance of 6.25 m west of the lowest step to the presbytery, there is an excellently preserved Gothic floor, a brownish screed interspersed with small white limestones. A 0.89 m wide and 1.37 m long granite stone slab with two heavy iron rings covers the entrance to the crypt (Zemmer-Plank 1985, 26, fig. 2). Beneath the stone slab a stair leads to a small room (1 m wide, 0.9 m deep and 1.24 m high) that served as an antechamber to the actual burial room (Zemmer-Plank 1985, 26-27, fig. 3 and fig. 4). A double-winged wooden door separated it from the burial chamber as some wood residues and two iron cones on both sides of the stone doorframe show. The bottom of the burial chamber with a barrel-vault lies around 0.35 m lower than the antechamber. The crypt is 2.4 m long, 1.05 m wide with a maximum height of 1.69 m. The vault starts at 1.2 m height at the two longitudinal walls. The wall plaster was applied without special care and has partially flaked off so that the stones are visible between the unsmoothed mortar zones. On the vault of the burial chamber the imprints of six 0.2 to 0.28 m wide wooden boards can be seen. The dirty brown screed is rough and uneven. On the floor of the crypt, in the eastern part of the burial chamber, five human skeletons lay pushed together. Their disorder in the crypt was so extensive that the skeletons were torn completely out of their original context. There was no anthropological investigation done and unfortunately Zemmer-Plank, who excavated the crypt, made no note in her site notebook if she was able to distinguish between skeletal remains of children and adults, male or female. The photographs taken inside the crypt are inconclusive and the bones were reinterred. It cannot be determined when this disturbance took place. Perhaps when the table tomb was dismantled in 1781 (Pizzinini 1973, 232) or during the restoration of St Andrew in 1860, when a new floor was laid, and the stone slab covering the entrance to the crypt disappeared under it. Mixed with the bones was an approximately 0.25 m high pile of debris consisting of crumbled plaster, wood scraps from the coffins and the wing door, iron bands and hinges and remains of the grave goods. A sword with a long, narrow blade, fragments of a pair of bronze wheel spurs with the associated buckles, fragments of garments and a rosary with wood and jet beads were also found (Zemmer-Plank 1992, 139-140, fig. 12.15).

From the garments, only a few indefinable fragments made of fine linen, set with a 50 mm wide velvet border and a 7 mm wide dagged edging, including one probable sleeve part, remained. A very coarse piece of fabric in twill weave about the size of a palm of undetermined use was still present too. From the footwear, only some leather pieces could be salvaged and the soles of a pair of shoes. Because of their size, they must have belonged to a petite woman or to a child. Only two heels of spruce (20 mm high, 57 mm wide and 85 mm long) as well as the fragment of a shoe sole or patten made from cork with a preserved length of 106 mm and a width of 74 mm and two leather soles of a total length of 200 mm and a maximum width of 70 mm width (measured at the forefoot and heel) were found (Zemmer-Plank 1992, 136 & 140, fig. 12.14, 139). The soles are rounded at the toe. From the shoe upper, just some small fragments provide no clues about the design of the footwear. Amazingly well preserved were four pieces of headwear, a padded roll with ties, two hairnets and a coif. As with most finds from graves all objects now show a uniform brown colouring, and the original shades cannot be determined.

The reason why the four pieces of headwear are much better preserved than the other textiles is unknown. It could be due to the material, since the various plant and animal fibres react differently to moisture, temperature, oxygen, and other soil conditions such as pH-value and salinity, or it could be due to their position in the coffin – on the head – where they were less exposed to the decomposing bodies.

Which five members of the house of Wolkenstein-Rodenegg were buried in the crypt in St Andrew´s? First, Barbara von Thun and Michael von Wolkenstein-Rodenegg and maybe two of their seven children[1], Philipp and Bianca, who died at a juvenile age (Zemmer-Plank 1985, 27). This was also the opinion of Zemmer-Plank who saw the skeletal remains. Therefore, it must be assumed that she identified at least some of the bones as being those of juveniles, even if she failed to make a note. The fifth was probably their son Veit von Wolkenstein-Rodenegg. Zemmer-Plank writes that he was buried *in monasterio* in Lienz, information that she gathered from the ´genealogies of the Tyrolean nobility´, by Stephan von Mayrhofen. This is a misunderstanding. The entry *sepulta in monasterio* (Mayrhofen n.d., 844) refers to the burial place of his wife Susanna von Welsperg (died 1580). Veit died in 1538 when the crypt of his parents was still relatively new. His wife Susanna outlived him by 42 years. By then the tomb had not been used for decades. It is also much more plausible that a widow like Susanna entered a convent in her old age and was then subsequently buried there, than Veit, who died – probably unexpected – at the age of 31.

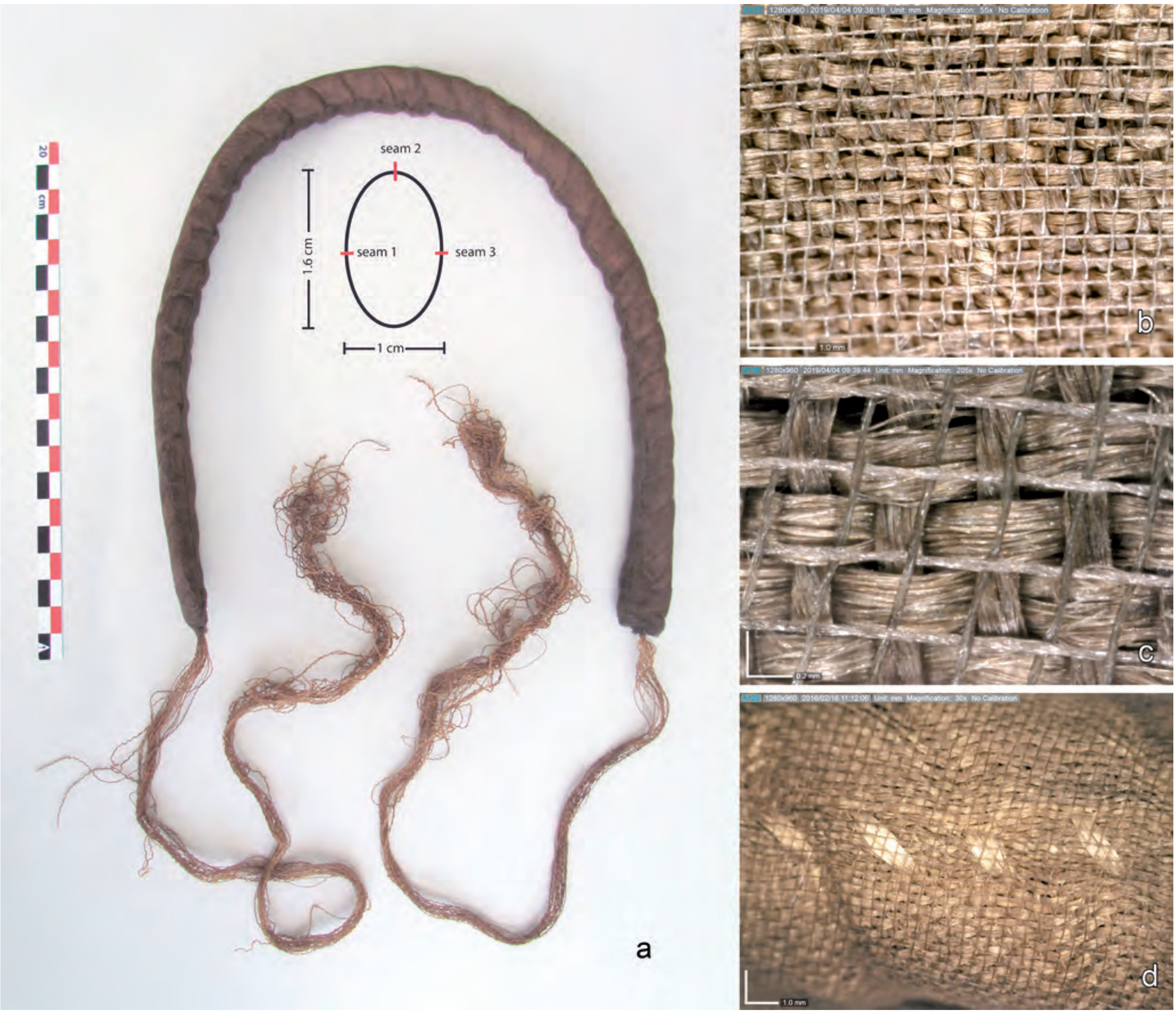

Fig. 2: a) padded roll or wulst from the crypt; b) – d) microscope images of the fabric seen through the meshes of the crepeline cover. Magnification of b = 55 x, c = 205 x, d = 30 x (© Tyrolean State Museum Ferdinandeum. Images: Beatrix Nutz)

The textile finds from the crypt

The textile finds from the crypt of Michael von Wolkenstein-Rodenegg and his wife were first published 1985 by Liselotte Zemmer-Plank in the *Festschrift* (commemorative publication) for the 65th birthday of Erich Egg (Zemmer-Plank 1985) even though She admitted that textiles were not her area of expertise. In addition, the paper is written in German and did not gain the international attention it deserves. The finds are now housed at the Tyrolean State Museum Ferdinandeum in Innsbruck, inventory number TLMF U 18.475. Liselotte Zemmer-Plank passed away on 19 May 2015 and is sorely missed by her colleagues. In her memory, the textiles were re-examined and the results are to be published in English to make them known to a wider audience. Elisabeth Macho-Biegler (*Atelier für Textilrestaurierung*, e-mail: textilrest.emb@gmx.at) conserved two of the textiles in 2000, as they were put on display in a temporary exhibition (Zemmer-Plank 1992). To stabilize the fragile objects, a padded roll or *wulst* and a knotted hairnet were covered with silk crepeline. The *wulst* is completely encased except for the two ties at the ends and the hairnet is sewn onto the crepeline, which now obscures the inside as well as the damaged lower parts of the hairnet on the outside. Unfortunately, this makes it difficult to obtain all data needed (e.g. weave and thread count of the fabric of the *wulst*, type of knots with pile used and bottom finishing on the hairnet). It was also not possible to analyse the fibres according to modern standards, as the museum did not give permission to take fibre samples. In her conservation report Elisabeth Macho-Biegler identified the fibres of the knotted hairnet as silk and Zemmer-Plank wrote that the *wulst* is made of linen, but neither provided information on how they achieved this identification. Personal communication with Mrs Macho-Biegler in 2019 provided no additional information as she could not remember how she identified the fibres as silk. The re-examination of the textiles was done visually only using photography, macro photography and microscope images taken with a Dino-Lite-Microscope.

The headdresses

The padded roll

The padded roll or wulst is 505 mm long (without ties), 16 mm wide and 10 mm thick (fig. 2a). It is made from three strips of fine fabric sewn together with whip stitches (fig. 2d) using sewing thread with a thread diameter of 0.66 mm and stuffed with stiff matter. As mentioned above, according to Zemmer-Plank, the fabric is made of linen, but the threads show no easily discernible twist when looked at under a Dino-Lite-microscope with 60 x magnification giving the impression of reeled silk (fig. 2b and fig. 2c). The warp threads do appear to have a very slight S-twist, which seems to be a characteristic of silk yarn used in Italian silks in the 15th to 16th century, while older silks are woven with Z-twisted yarns. This change is probably associated with a technical development in silk throwing (Crowfoot et al. 2012, 124). Lisa Monnas and Roberta Orsi Landini wrote on S-twisted silk threads: ´fourteenth-century [Italian] velvets usually have Z-spun main ends … but from the late 1420s their main warp threads were generally S-twisted. In contrast, Ottoman velvets of the late 15th and 16th centuries generally have Z-twisted main warp threads´ (Monnas 2012, 15); 'the finest silk thread was used for the warp: strong shiny silk organzine, generally made up of 2 S-twisted ends' (Orsi Landini 2017, 15-16).
The thread diameters range from 0.2 mm (warp) to 0.3 mm (weft) and the fabric is woven in plain weave with 30 threads/cm, although it occasionally appears that two threads are used in the weft in the same shed. The ties are each 450 mm long and are now a loose bundle of eighteen wavy threads once most likely either plied or braided to form a cord. The material of the padding could not be determined but it could be made from cotton, strips of fabric or even bast. Cotton padding was often used for doublets, duvets or sleeping caps

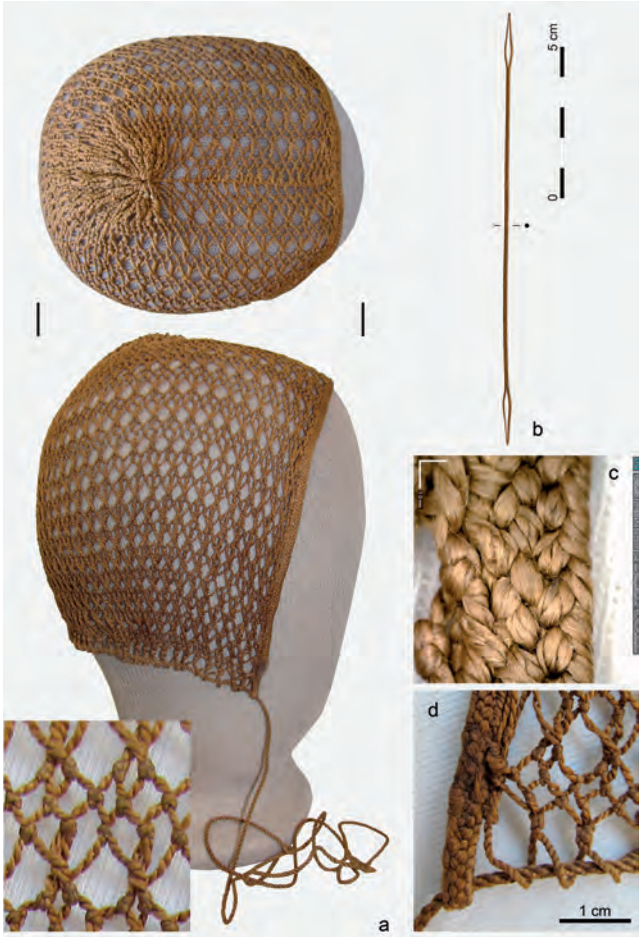

Fig. 3: a) netted hairnet; b) filet needle; c) braid – microscope image, magnification 35 x; d) drawstring running through the last row of netting loops and the loop at the end of the braid (© Tyrolean State Museum Ferdinandeum, Image: Beatrix Nutz. Filet needle: © Museum Schloss Bruck Lienz. Image: Südtiroler Landesmuseum für Kultur- und Landesgeschichte Schloss Tirol)

(Zander-Seidel 1990, 398) and of two 15th century rolls found at Lengberg Castle (Nutz 2015b, 29 and 30 fig. 4) one was stuffed with strips of linen fabric and one with lime bast, *Tilia* cf *cordata* (analysis by Thilo Kappelmeyer in 2013).

Netted hairnet[2]

The hairnet is made from a rectangular piece of netting of 220 x 500 mm with an S-plied 2-ply thread with a thread diameter of 0.75 mm (fig. 3a). The fine mesh suggests that it was made using a filet needle. Such a needle (length 153 mm, fig. 3b), dated to the 16th century was found in a vault at Bruck Castle (Datterl 2009, 51), where the family of Wolkenstein-Rodenegg resided. The rectangular net is folded and ´sewn´ together on one longitudinal side by running a thread through the loops and winding another thread

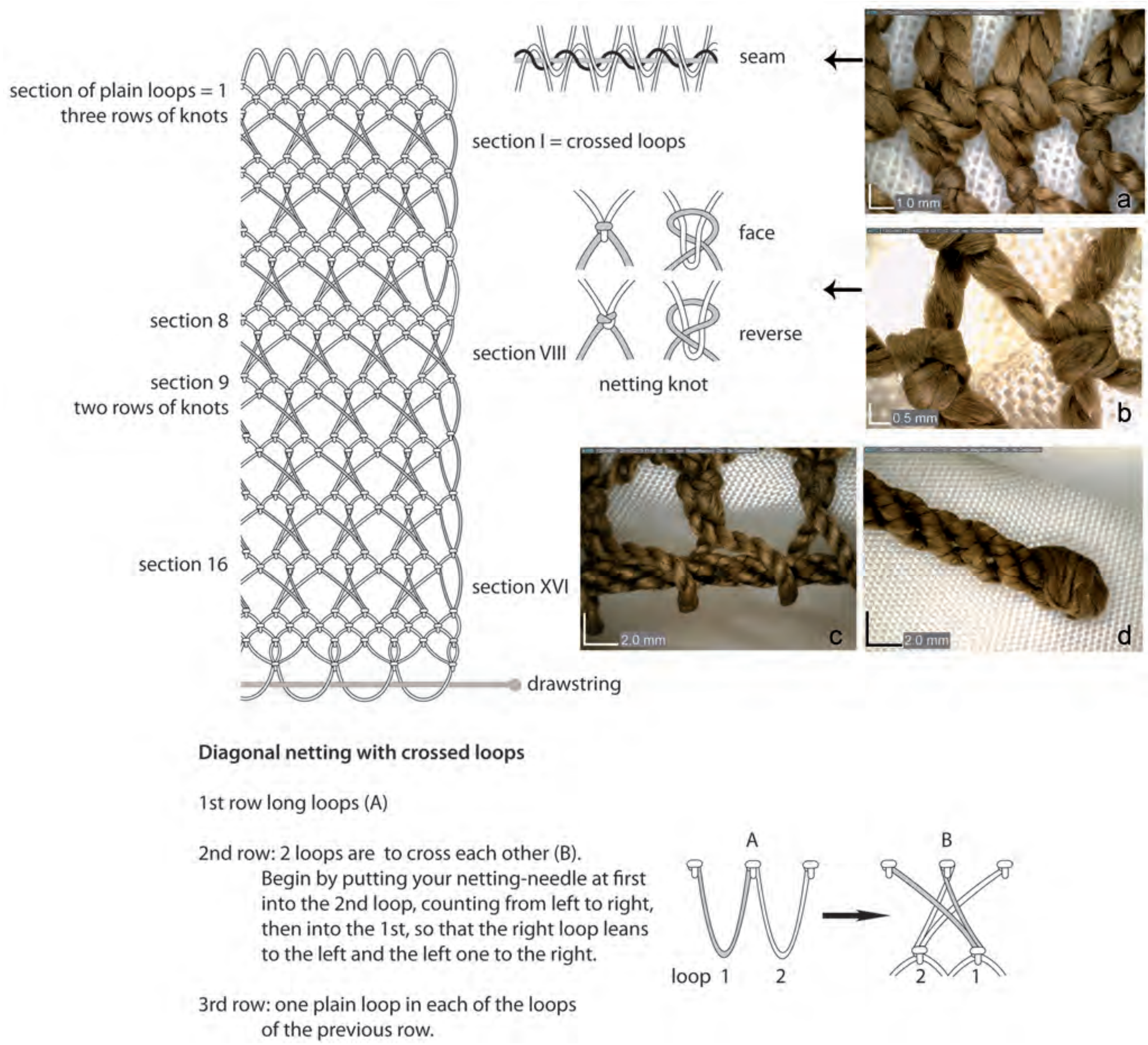

Fig. 4: Pattern of the netted hairnet with microscope images. a) the ´seam´; b) the netting knots; c) and the drawstring; d) the knotted end of the drawstring. Magnification of a = 35 x, b = 60 x, c and d = 25 x (© Tyrolean State Museum Ferdinandeum. Images: Beatrix Nutz)

as ´spacer´ around the said thread. This side is then gathered at the back of the head leaving a seam of 75 mm length. A narrow, 550 mm long and 4 to 5 mm wide braid is sewn onto the edge of the face opening, both ends folded to make 25 mm long loops (fig. 3c and fig. 3d). The braid with a slightly D-shaped cross section, flat on one side and ridged on the other, was most likely done in a loop manipulation technique in a pattern in 15th century braiding manuals called ´a broad lace of five loops´ (Speiser 2000, 49; Benns & Barrett, 2007, 39). Through the last row of netting loops at the bottom edge and the loops of the braid runs a 1970 mm long and 2 mm thick drawstring with knotted ends made of three threads (fig. 4c and fig. 4d). The pattern consists of alternating sections of plain loops and crossed loops (16 sections of crossed loops in total) (Dillmont 1890, 397–398). Thérése de Dillmont explains ´diagonal netting with crossed loops´ for the

Fig. 5: a) 16th century hairnet with netting knots using increases and decreases in the Bisschoppelijk Palais in Ghent (Belgium); b) knotted hairnet with gold and silver wire in the Bisschoppelijk Palais in Ghent (Belgium) with close-up of the knots (© KIK-IRPA, Brussels, Object numbers 93124 and 93121)

crossing of three loops, but here only two loops are crossed (Dillmont 1890, 406-407, fig. 632). The pattern changes slightly after the eighth section of plain loops from a line composed of three rows of knots to two rows of knots in between the crossed loops (fig. 4). The net is finished with a row of decreasing loops for the drawstring (Dillmont 1890, 400). A comparable 16th century hairnet using increases and decreases is housed in the Bisschoppelijk Palais in Ghent (Belgium) (fig. 5a).

The decreasing loops of the hairnet are characteristic of a netting technique called *mezzo* (or *mezza*) *mandolina*. According to Margaret Abegg *mezzo mandolina* is a variety of network (Abegg 1978, 94). It is an irregular mesh that employs increases, decreases, different stitch lengths, dropped and added stitches, to create the decorative effect. It is sometimes left plain, like the hairnet from Lienz, but more often it is embroidered in darning stitch which fills the mesh so that the background can hardly be seen between the interwoven figures. Ricci published a photograph of a plain, unembroidered net with decreases on fig. 39 and believes the embroidered chemisette (or partlet) of Eleanor of Toledo in her portrait by Agnolo Bronzino, circa 1560, to be a *mezza mandolina* net (Ricci 1913, fig. 38 and fig. 39). Levey (1990) identified the partlet worn by Isabella de Medici in her portrait by Bronzino (circa 1552-1553) as being *mezza mandolina*, but thinks the partlet of Eleanor of Toledo is of *burato*, decorated in imitation of *mezza mandolina* (Levey 1990, fig. 98 and fig. 103). *Burato* is worked on a ground fabric woven with an open gauze weave resembling the regular mesh of the hand-knotted net (Levey 1990, 18-19). Patterns for *mezzo mandolina* can be found in Isabetta Parasole's *Specchio delle virtuose donne* published in 1595 and in *Studio delle virtuose dame* 1557 (Parasole Catanea 1595; Parasole Catanea 1597). If the hairnet from Lienz can indeed be labelled *mezza mandolina* however is debatable. Johnstone describes the *punto a mezza mandolina* as "stitch of half an almond shape" (Johnstone 1926, 16). This is an acceptable translation of the Italian term, as *punto* can translate to ´stitch´, *mezzo* to ´half´ and *mandolina* to ´almond-shaped´. Pat Earnshaw gives both Abegg´s and Johnstone´s opinions and says that the latter describes the simplest form of buttonhole stitch loop (Earnshaw 1999, 110). Levey and Lewandowski define it as 'a form of lacis where the large square mesh is covered by a cobweb-like pattern of darned thread' (Levey 1990, 122; Lewandowski 2011, 191). It is possible that *mezzo mandolina* either just refers to the type of stitches used to ´embroider´ the knotted net or to both the net and the embroidery. Looking at Parasole´s patterns it is most likely both.

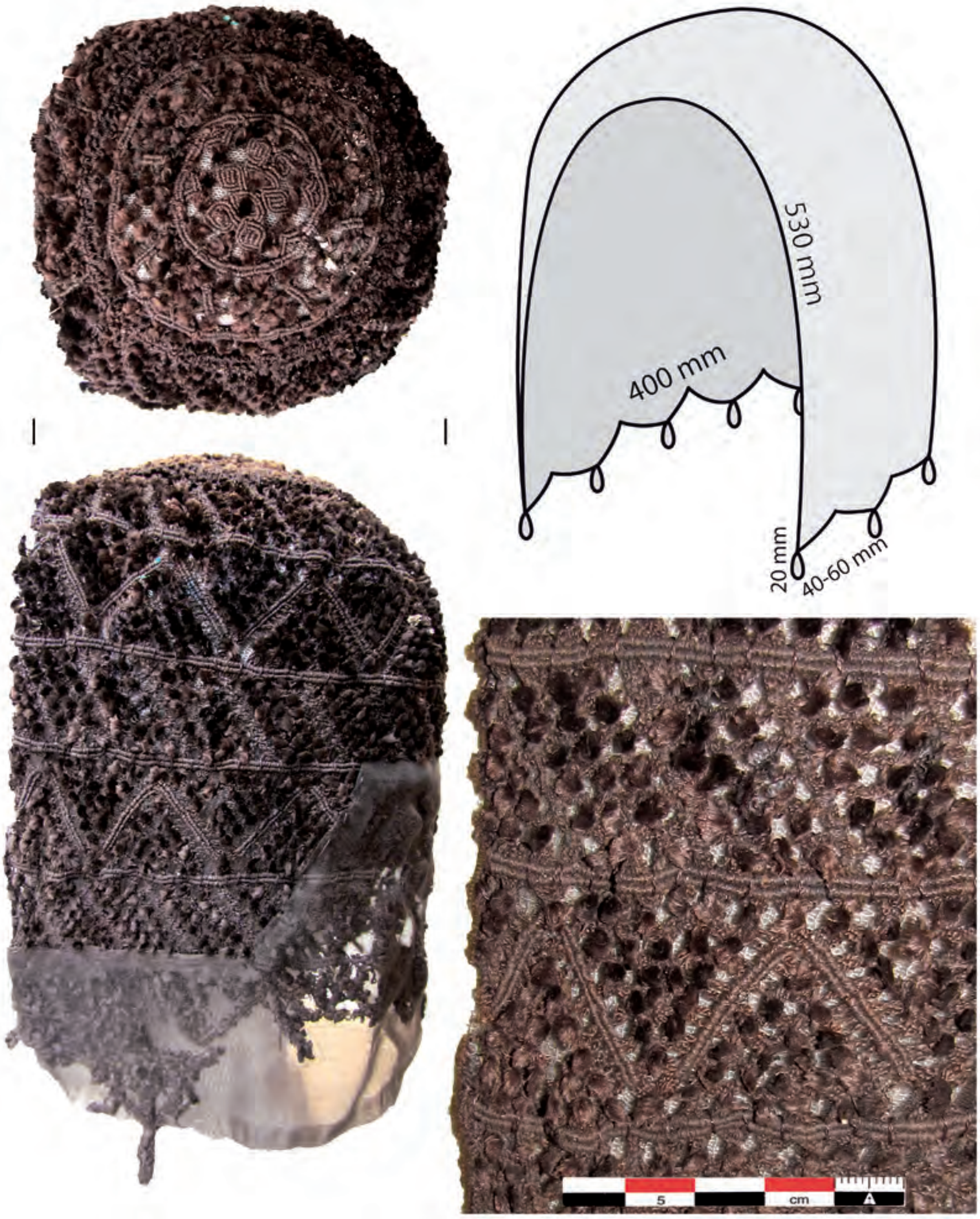

Fig. 6: Knotted (macramé) hairnet with measurements and close-up (© Tyrolean State Museum Ferdinandeum. Images: Beatrix Nutz)

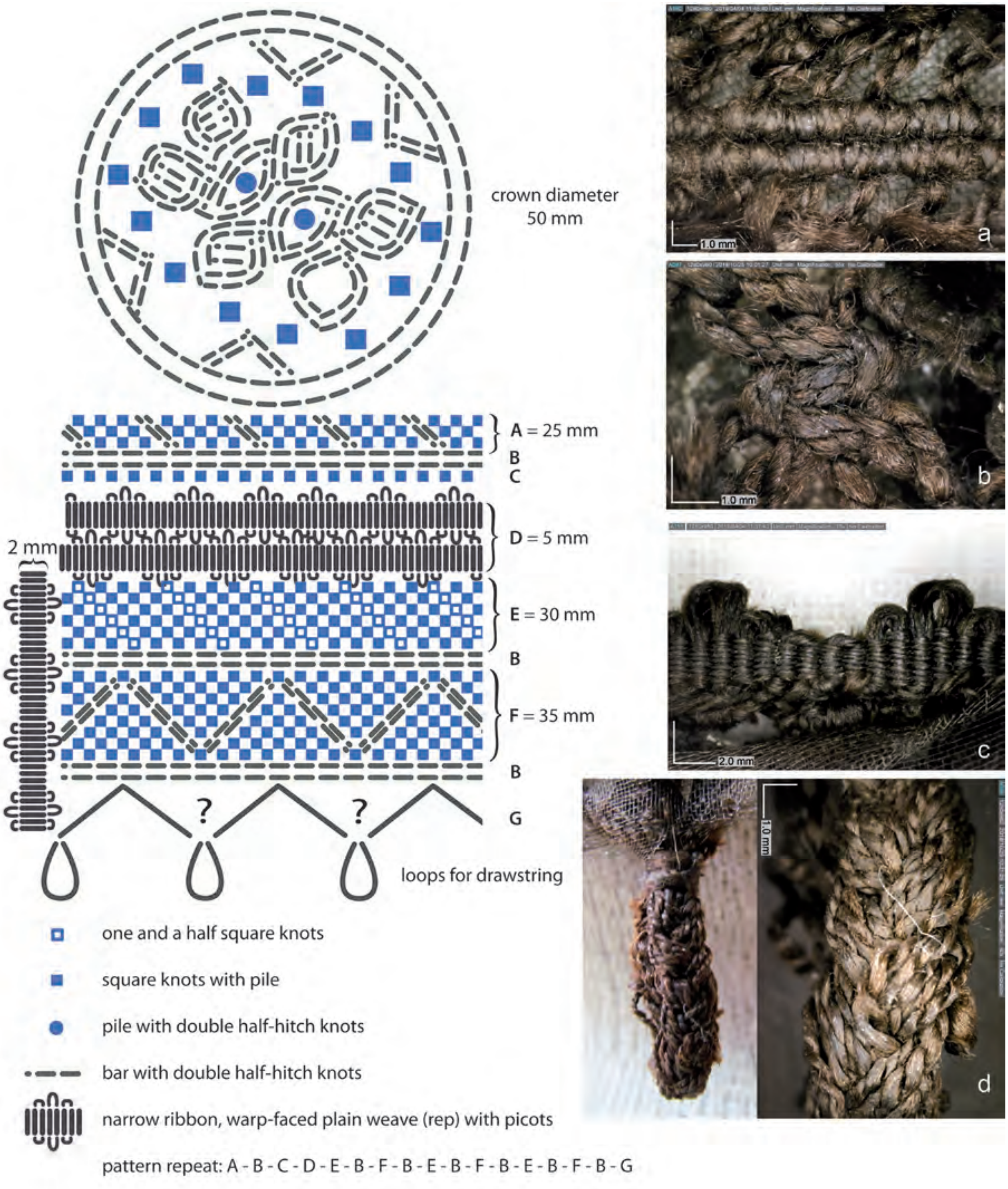

Fig. 7: Pattern of the macramé hairnet with microscope images. a) the half hitch knots; b) the one and a half square knots; c) the rep ribbon with picots; d) the loops for the drawstring with close-up (left) and microscope image (right). Magnification of a = 30 x, b = 55 x, c = 25 x, d = 40 x (© Tyrolean State Museum Ferdinandeum. Images: Beatrix Nutz)

Knotted hairnet

The second hairnet is worked from the top of the head down, starting with a circular centrepiece (also called an eye or crown) with swirls (fig. 6). The centrepiece is followed by concentric strips alternating between diagonal and triangular patterns separated by bars of horizontal half-hitch knots (fig. 7a) adding threads as the diameter increases (fig. 8b). The first diagonal pattern row is followed by two very narrow ribbons in warp-faced plain weave or rep (Emery 1994, 76-77, 86) with a width of 2 mm each that are sewn onto the hairnet and obscure the knots underneath. The same

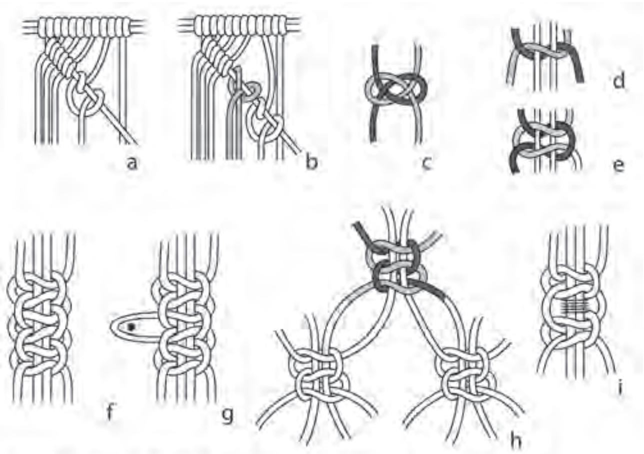

Fig. 8: Macramé knots (Image: Beatrix Nutz)

type of ribbon frames the face opening of 530 mm. The weft thread of this ribbon is used to make picots (fig. 7c). The bottom ends in several V-shaped points, but the exact pattern of the V cannot be determined due to extensive damage and the crepeline cover. At the tips of the V´s the threads used for the knots are gathered, braided and the braid turned over to form a 20 mm long loop (fig. 7d) for the now missing drawstring. The surviving loops are 40 mm to 60 mm apart which would make about eight loops in total. The knots are of a type that is commonly known as macramé knots today and the pattern is achieved with bars of double half-hitch knots (fig. 8a), square knots or Solomon knots (fig. 8e) and one and a half square knots (Emery 1994, 65) (fig. 7b and fig. 8h). Small fibre bundles (pile) are knotted into the hairnet with square knots (fig. 8i). Comparable hairnets with macramé knots are found in the Czech Republic and Hungary.

The hairnet of Anne of Bohemia and Hungary, also known as Anna Jagellonica (born 1503 – died 1547), daughter of King Vladislaus II of Bohemia and Hungary and the wife of Emperor Ferdinand I, that was found in her tomb in St Vitus Cathedral in Prague and a hairnet found in a well at Prague Castle dating before 1580 (Archive of Prague Castle, inventory numbers PHA 25/2 and PHA 40) both use square knots (Czech: plochý uzel). But in contrast to the hairnet from Lienz they also employ other techniques such as needle lace and embroidery (Bravermanová et al. 1994a; 1994b; Bravermanová 2005; Fučíková 1997, 592; Súkeník 2013, 55-56). The hairnet of Anna Jagellonica is described as ´a cap made of gold thread with a bottom band of woven cloth from which there is a sewn central medallion made in openwork from "columns" of thread. Gold thread is fixed around the circumference, and out of it the cap is made in knot-work´ and its origin as ´probably Italy, Germany or Austria, made up probably in Vienna or Prague´

Fig. 9: Hairnet with macramé knots found in St Martin´s Church, Szombathely, Hungary (© Dominican Monastery and Museum Vasvár)

Fig. 10: Portrait of Barbara Schellenberger, née Ehem, 1507, by Hans Burgkmair. Cologne, Wallraf-Richartz-Museum & Fondation Corboud, Gemäldesammlung, Inv.-No. WRM 0851 (© Rheinisches Bildarchiv, rba_c004538)

(Fučíková 1997, 592). It is additionally covered with a silk muslin veil. In portraits of Anna painted by Hans Maler zu Schwaz, she can be seen wearing hairnets underneath large caps. Schwaz was a German painter active as a portraitist in the village of Schwaz, near Innsbruck in North Tyrol. His clients were members of the Habsburg court in Innsbruck and Schwaz merchants, especially members of the Fugger family. He portrayed Ferdinand I at least three times and Anna of Bohemia and Hungary four times (Mackowitz 1960, 42-46).

The hairnet from St Martin (parish church until 1638) in Szombathely, Hungary (fig. 9), found in situ in grave number 16 likewise is made with rows of square knots (fig. 8f), some with picots (fig. 8g) (Sipos 1998). The grave, excavated in 1992 by Gábor Kiss, situated next to the high altar of St Martin belonged to a young woman of about 18 to 20 years, buried in a wooden coffin. Apart from the hairnet, remains of

Fig. 11: Coif with bobbin lace edging (© Tyrolean State Museum Ferdinandeum. Images: Beatrix Nutz)

her garments and a belt with silver fittings survived. The burial is dated to the end (or last third of) the 16th century, certainly before the year 1605. The hairnet is made of gilded silver threads. The eye on the top of the head is made of a handful of sewn lace rosettes framed by an embroidered net, followed by a slightly narrower braid. The macramé starts at the outer edge of the braid and the meshes are decorated with drop-shaped spangles cut from gilded silver plate, which were attached to the net with a metal thread (Sipos 1998, 233-234). The spangles and the metal threads are reminiscent of the *Flinderhaube*, *Goldhaube* or *Haarhaube* (hair cap/coif/net). With the *Haarhauben* the complete covering of the hair was first abandoned and the hairnets, worn with a free, high forehead, clearly show Italian influence. The *Haarhaube* was in fashion in Italy and with the nobility as early as the 15th century, and appears on portraits of German women of the urban upper class from the late 1490s. Such hairnets were worn by married women and young girls alike, alone or covered with a veil, decorated with wreaths and hoops, and with or without wimples. On the occasion of her wedding with Hans Schellenberger, the 19-year-old Augsburg woman Barbara Ehem was portrayed in 1507 by Hans Burgkmair with a hairnet where the hair at her temples is visible (fig. 10) (Zander-Seidel 1990, 119; Zander-Seidel 2010, 39-40, fig. 3). Incidentally the gold spangled headdress of a Nuremberg patrician woman, dated 1650/1700 is also made with rows of square knots in gold-coloured silk thread (Germanisches Nationalmusum, inventory number T35). Another hairnet made with gold and silver wire, today in the Bisschoppelijk Palais in Ghent (fig. 5b) dated to the 16th century also uses one and a half square knots and Josephine knots (fig. 8c). In

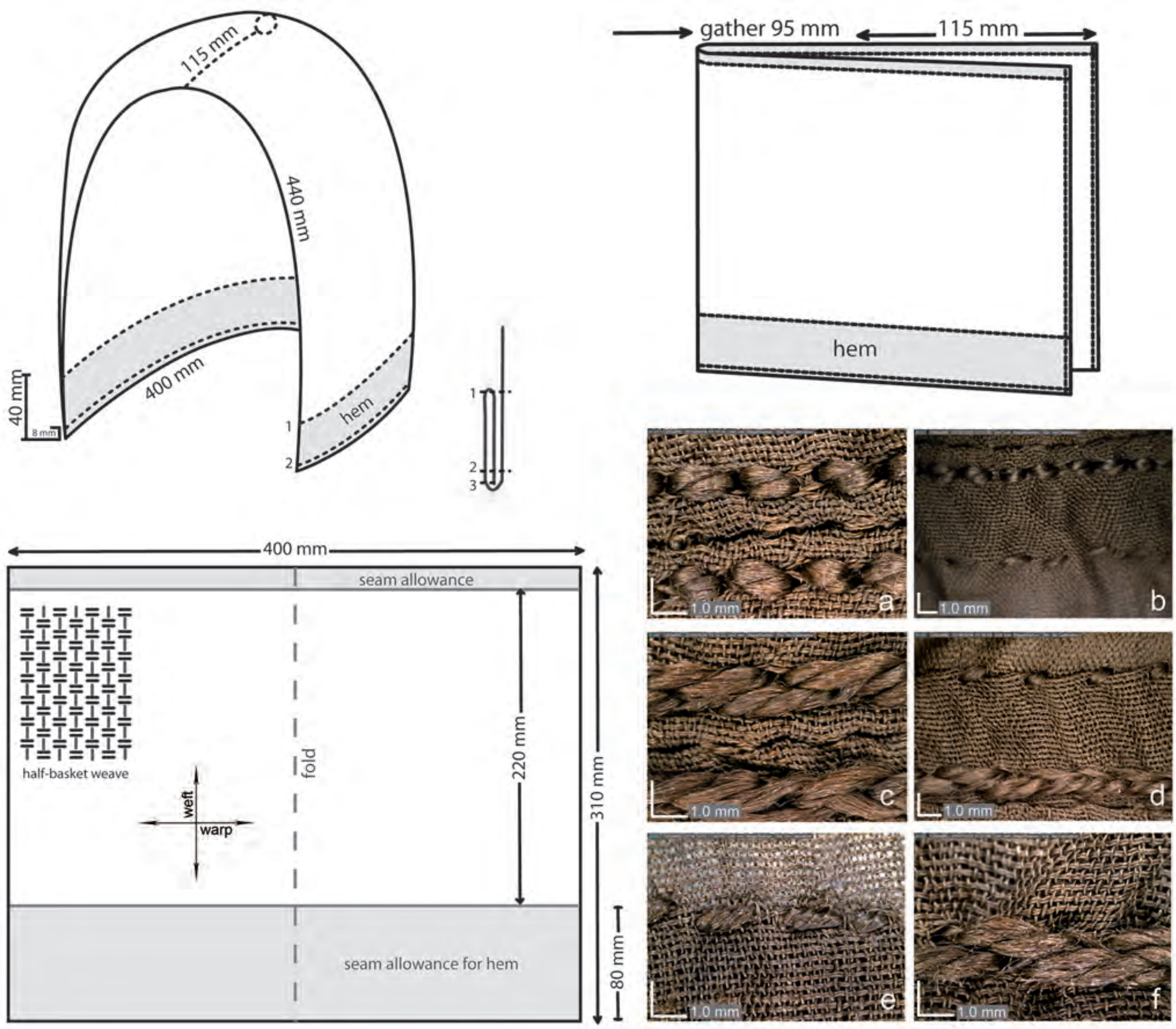

Fig. 12: Pattern with measurements of the coif. Microscope images. a-b) the seam at the parting outside; c-d) the seam inside; e) the bottom edge outside; f) the bottom edge inside. Magnification of a, c, e and f = 55 x, b = 30 x, d = 35 x (© Tyrolean State Museum Ferdinandeum. Images: Beatrix Nutz)

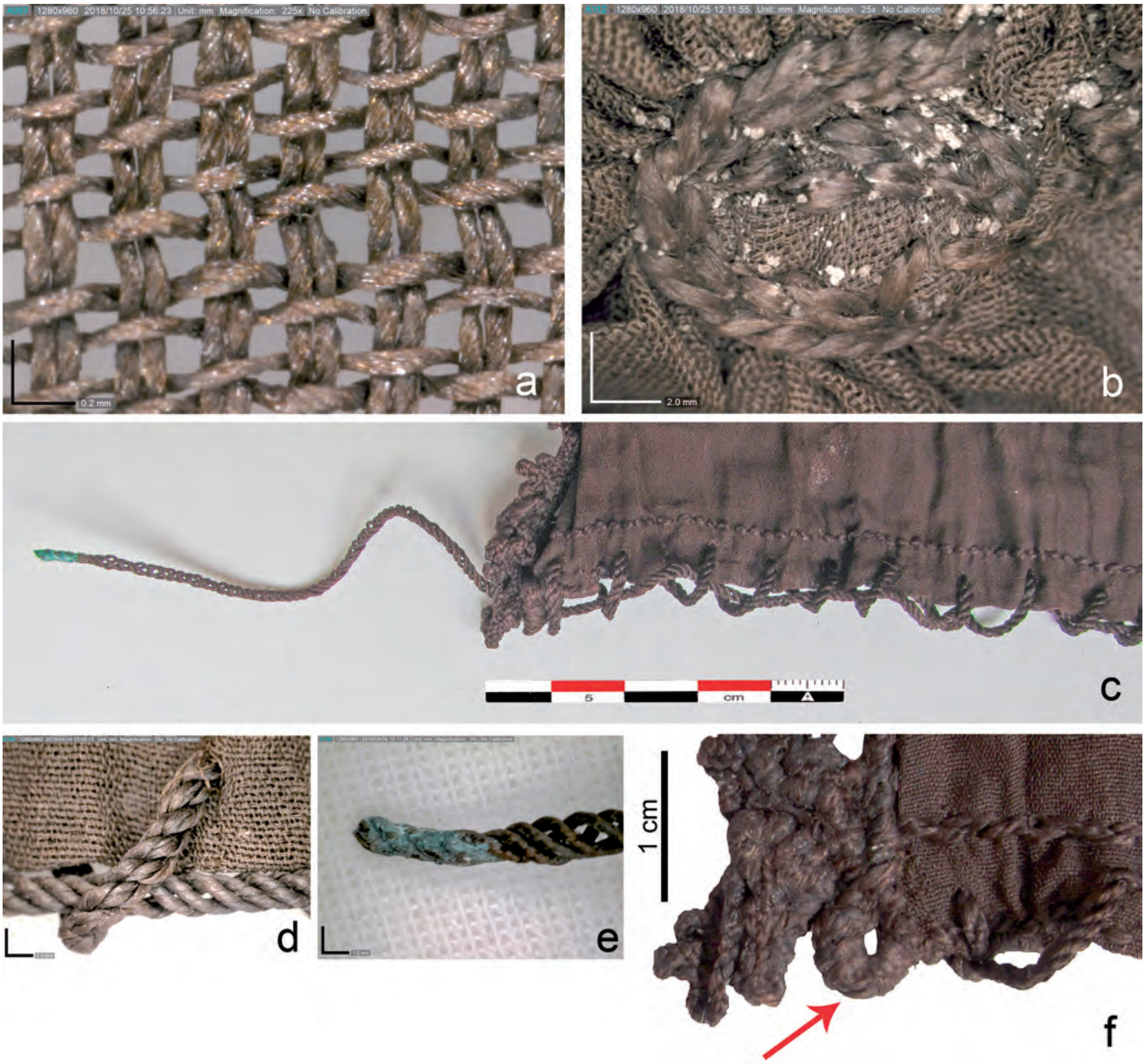

Fig. 13: Close-ups and microscope images of the coif. a) fabric; b) stitches at the gathering; c and d) string threaded through the holes to serve as loops and the drawstring; e) green staining on the end of the drawstring; f) end of the bobbin lace with loop. Magnification of a = 225 x, b = 25 x, d and e = 35 x (© Tyrolean State Museum Ferdinandeum. Images: Beatrix Nutz)

a painting by Agnolo Bronzino[3] (circa 1560) Eleonora di Toledo can be seen wearing a similar hairnet with Josephine knots.

The coif

The coif (fig. 11) is a similar shape to the netted hairnet as it too is made with a rectangular piece of fabric of 315 x 400 mm, folded, sewn together at one longitudinal end and gathered at the back of the head (fig. 13b), leaving a 115 mm long seam at the parting (fig. 12). The very fine, transparent fabric is woven with Z-twisted yarn with a diameter of 0,065 to 0,09 mm and a twist angle of 29° in half-basket weave (Emery 1994, 77, 87) with 70 weft threads/cm and 40 double warp threads/cm (fig. 13a). The bottom edge is folded twice to make a 40 mm wide hem sewn with three rows of back stitches (fig. 12e and fig. 12f). At intervals of about 10 mm, holes are punched into the very bottom of the fabric without any overstitching to create eyelets (Crowfoot et al. 2012, 164; Case et al. 2017, 170) and a string is threaded through the holes to serve as loops for the drawstring. Both strings are 14 mm thick and made with four S-plied, 2-ply threads Z-plied together. The drawstring has a preserved length of 340 mm, and the green staining at the remaining end indicates lace chapes of nonferrous metal (fig. 13c to fig. 13e). The 440 mm long face opening is hemmed and decorated with an 11 mm to 12 mm wide bobbin lace. The lace is made with 12 bobbins using S-plied thread with a diameter of 0.8 mm and the pattern called Krönle mit XII (crown with 12 bobbins) in the Nüw Modelbuoch of 1561 (R. M. 1561). The same pattern but with additional picots appears in the Le Pompe, volume one of 1557 (fig. 14). The braid at the straight edge of the lace is folded on

Fig. 14: Bobbin lace. a) on the coif with patterns from the *Le Pompe* and the *Nüw Modelbuoch*; b and c) Microscope images of the lace; d) structure of 4-strand plait. Magnification of b = 20 x, c = 55 x (© Tyrolean State Museum Ferdinandeum. Images: Beatrix Nutz)

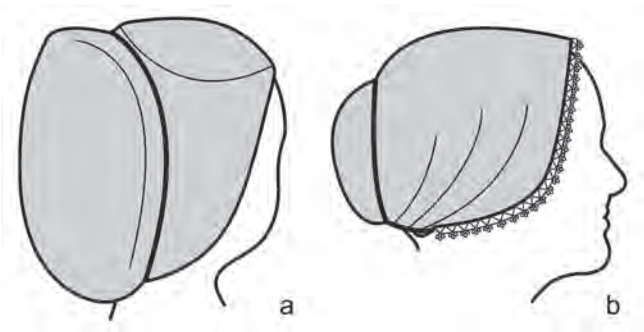

Fig. 15: How to wear: a) the macramé hairnet; b) the coif (Image: Beatrix Nutz)

both ends to make loops for the drawstring (fig. 13f – red arrow) and the lace is sewn on to the coif with whip stitches. Due to the lace and the whip stitches obscuring the edge of the fabric it is not possible to detect a hem. The coif is well preserved except for the left side where the bobbin lace has been partially torn off the edge.

Who did the headdresses belong to and how were they worn?

The macramé hairnet and the coif with bobbin lace most likely belonged to Barbara von Thun. Hairnets of this type were female headwear as the hairnet from the tomb of Anna Jagellonica and from the grave in St Martin, Szombathely show. The macramé hairnet was probably given shape by a stiffener inside, as with the other two hairnets found in graves, and looked similar to the hairnet of Barbara Schellenberger, née Ehem, in her portrait of 1507 (fig. 10). The now missing drawstring is crossed at the nape and wrapped around the stiffener (fig. 15a).

The coif with the bobbin lace also appears more suitable for a girl or woman and might have been worn either on top of the macramé hairnet, much like the silk veil of Anna Jagellonica, or underneath the net. It makes more sense to assume that the coif is worn underneath the hairnet as wearing it on top would spoil the impression created by the fibre bundles knotted into the net. This way it would also prevent any stray hair from sticking out through the meshes of the net. Fortunately, this headdress was not restored and the creases in the fabric caused by wear can still be seen, suggesting that the coif was tied at the back, the drawstring crossing at the nape, as with the hairnet, and tied around a bun or padding (fig. 15b). Spots of green copper oxide (patina) on both the macramé hairnet and the coif indicate hairpins penetrated both layers. Coifs or veils of transparent fabric worn underneath a hairnet are depicted on various paintings of the 16th century such as the frescoes on the wall of the Golden Roof in Innsbruck (Weiss 2010, 104, fig. 106).

The netted hairnet does not seem to be gender specific and could have been worn by Barbara von Thun, Michael von Wolkenstein-Rodenegg or his son Veit. Yet, since it is unlikely that Barbara would have worn three headdresses at the same time, the netted hairnet was worn either by Michael or by Veit von Wolkenstein-Rodenegg. Michael, who was probably buried with parts of his equestrian harness (presumably the harness that can be seen on his effigy), as indicated by the wheel spurs and the sword, could have worn the hairnet underneath his helmet. For Veit, a rider's harness no longer necessarily belonged to the aristocratic symbol of class. He may have been buried in festive Renaissance clothing.

The *wulst* or padded roll is not thick enough to provide the large bumps seen on a *Wulsthaube* or *Steuchlein* such as the one on Barbara´s effigy, but there are three other possibilities for its use. Liselotte Zemmer-Plank thought the *wulst* was used as a padded headband (*Stirnwulst*), originally embroidered or adorned with metal lace, to be worn alone or with a veil (Zemmer-Plank 1985, 28–29, fig. 5). Since the *wulst* is now covered by silk crepeline it is not possible to see if there are any holes in the fabric indicating that a needle and thread was used for embroidery or to sew on lace. This headband would not have covered the hair, as was proper for a married woman and therefore could only have belonged to Barbara´s daughter Bianca, depending on how old she was at the time of her death – which is not known. The portrait of one of the daughters of Leopold III, Margrave of Austria, on the Babenberg family tree in Klosterneuburg, painted 1489-1492 by Hans Part, shows how this supposed decorated headband could have been worn (Klosterneuburg Stiftsmuseum, GM 86 and Nutz 2015a, 103, fig. 8). It is much more likely that the *wulst* was used together with one of the hairnets. With the macramé hairnet, the *wulst* would have been used as stiffener at the back of the head or it might have been worn on top of the head underneath the netted hairnet, even if this hairnet belonged to one of the men in the tomb. Men sometimes also wore a *wulst* under a coif or hairnet, in a similar style to woman. In the estate account of Lazarus Holzschuher of 1545, a *guldin Hauben mit sampt dem wulst* (a golden cap/coif with the *wulst*) is listed among other possessions (Zander-Seidel 1990, 230 and fig. 212).

Dating the headwear

For the same reason that no fibre analyses were done, none of the finds from the crypt were radiocarbon dated. Acting on the assumption that Veit von Wolkenstein-Rodenegg was the last person to be buried in 1538, all the grave goods must date to, or pre-date 1538. If the macramé hairnet and the coif with the bobbin lace indeed belonged to Barbara von Thun they date no later than 1509 or are even older, assuming she owned and wore them for some time before her death. This would place both headdresses among the oldest, if not the oldest, surviving examples of the techniques of macramé and bobbin lace known to date. In comparison with the hair nets of Prague and Szombathely, the macramé hairnet of Barbara von Thun is relatively simple. It was, apart from the narrow rep-bands, only worked with macramé knots using silk thread. The hairnets from the Czech Republic and Hungary are more elaborately worked, combine several textile techniques, and also use metal threads and spangles, demonstrating the development of a simple to a complex, elaborate and almost excessive style. If this type of hairnet and macramé did indeed originate in Italy, it is feasible that the technique and the fashion reached Tyrol, before it spread further north and east. The same can be said about bobbin lace that develops from rather simple braid-like laces to ever more complicated patterns.

Some thoughts on the history and development of macramé and bobbin lace

Macramé

Macramé is an ancient technique whereby a row of vertical threads is knotted into a decorative pattern (Levey 1990, 122). The primary knots of macramé are the square knot and various combinations of half-hitches. Some books on macramé include the Josephine knot (Sylvia 1890, 296).

The term macramé is believed to be related either to the Arabic word *maqrama* (or *mahramatun* – Lunghi & Pessa 1996, 32), meaning ´towel´, or to the Moorish word *miqramah*, meaning ´striped towel´ (Levey, 1990, 5) or ´ornamental fringe´ (Lunghi & Pessa 1996, 32). Both suggest that it was based on the use of loose warp threads, but it was also built up with long threads secured to a single head-thread pinned horizontally to a hard pillow. The horizontal position and the lack of bobbins (except for occasional use – see Dillmont 1890, 359-360), together with its knotted structure allows for no simple transition from macramé to lace. It seems that macramé and the other horizontal fringe techniques should be regarded as parallel methods, benefiting from the same fashions that created lace but not contributing directly to its development (Levey 1990, 5).

The technique of square-knotting probably first arrived in Europe with the Moorish invasion of Spain in 711. From Spain, where it was called *fleco morisco,* it might have been introduced to Europe. Or it could have been discovered (or re-discovered) during the Crusades, in the period 1095-1228. Returning crusaders´ ships carried the macramé art to Italy, notably Genoa (Carter 1998, 336). Nicoló Zoppino and Giovanni Tagliente may have been referring to it with the term *groppi moreschi* in their pattern books *Esemplario di lavori* (Zoppino 1529) and *Esemplario nuovo* (Tagliente 1531). Yet, although *groppi moreschi* may refer to macramé, none of the patterns appear suitable for this technique (Levey 1990, 121). Disagreement prevails between various authors over whether the term *punto groppo*, *punto a gropo*, or *gropari*, used by Pagano in 1542 for his designs *punti tagliati et gropposi*, refers to macramé. Palliser writes ´*Groppo*, or *gruppo*, signifies a knot, or tie, and in this lace the threads are knotted together, like the fringes of the Genoese macramé´(Palliser 1869, 44). Levey defines the term *punto groppo* as ´used to describe needle lace made with a densely-worked knotted buttonhole stitch; first found in the sixteenth-century pattern books and thought to refer to macramé but it probably indicated a pattern to be worked in knotted embroidery stitches´ (Levey 1990, 123). Sharp speaks of *punto a groppo*, or knotted lace, now known as macramé (Sharp 1913, 64), Lowes of *punto a groppo*, or macramé (Lowes 1908, 62) and for Hudson Moore all knotted laces are *punto a groppo*. ‘*Punto a groppo* made of cords similar to what is known as macramé. . . . *Punto a groppo*, or knotted lace, includes all the laces made of knotted cords´ (Moore 1904, 61, 80). In Earnshaw´s Dictionary of Lace the entry ´*Groppo, Punto a*´ contains several variants of knotted lace, (i) knotted buttonhole stitch, (ii) macramé, (iii) puncetto, (iv) groppi moreschi (Earnshaw 1999, 74-75). To add to this ´Babylonian chaos´, Florence May wrote that Moorish fringe (*fleco morisco*) was contemporary with macramé, suggesting that she believed it not to be the same technique, but also mentions *groppi moreschi et arabeschi* and *punto a groppo* in connection with macramé, and states that the province of Huelva made a great deal of macramé, but used the term *fleco morisco* (May 1939, 50–51). The term ´macramé´ itself appears for the first time in a document of 1584 in the *Capitoli dell'Arte dei Tovagliari* (ms., cart., sec. XVI-XVIII, Genova, Biblioteca Civica Berio, m.r.l.3.20) (Lunghi & Pessa 1996, 47).

The earliest pictorial records of knotted fringes occur in the 15th century. The tablecloth in the painting *The*

Marriage at Cana by the Master of the Catholic Kings, circa 1495/1497 (Washington, National Gallery of Art, Samuel H. Kress Collection no. 1952.5.42), shows a knotted fringe that could be made in macramé (Lunghi & Pessa 1996, 89, fig. 116). A knotted fringe (macramé?) can also be seen on the white and blue cloth hanging on the wall behind Maria on the fresco of the Annunciation by Joos Amann von Ravensburg in the cloister of Santa Maria di Castello in Genoa, painted in 1451 (Lunghi & Pessa 1996, 88, fig. 115). Surviving examples are few, and none of them would appear to date from before the late 16th century (Levey 1990, 19). The majority of the extant macramé pieces are flat, two-dimensional knotted fringes on towels, tablecloths or clothing. The hairnets, however are three-dimensional garments in their own right, and with the hairnet from East Tyrol most likely dating to 1509, and the hairnet of Anna Jagellonica dating no later than 1547, these are the oldest surviving examples of the technique of macramé in Central Europe to date. The hairnets also testify to the fact that macramé was not only employed in making fringes, unless the term macramé is restricted to two-dimensional knot-work without regard as to the type of knots used.

Fig. 16: a) Painting by Davide Ghirlandaio, *Portrait of a young woman*, circa 1490; b) close-up of possible lace (©Gemäldegalerie, Staatliche Museen zu Berlin, inventory number 83. Image: Volker-H. Schneider (CC) BY-NC-SA)

Bobbin lace

In the Encyclopædia Britannica, bobbin lace, sometimes also known as pillow or bone lace, because it is worked on a pillow and bobbins are sometimes made of bone, is explained as ´a handmade lace important in fashion from the 16th to the early 20th century. Bobbin laces are made by using a "pricking", a pattern drawn on parchment or card that is attached to a padded support, the pillow or cushion [author´s note: freehand lace is worked directly on the lace pillow without using a pricked pattern]. An even number of threads (from 8 to more than 1,000) are looped over pins arranged at the top of the pattern. Each thread is wound at its lower end around the neck of an elongated spool, or bobbin. Bobbins serve several purposes: their weight provides a tension that makes manipulation of the threads easier; they act as thread reserves; and they help to keep the thread clean by providing a surface other than the thread that can be touched frequently. In the creation of bobbin lace, each hand holds one of a pair of bobbins. The threads are crossed over or twisted around each other to produce solid areas of either linen-stitch (which resembles woven fabric) or half-stitch (a more open stitch), areas of decorative filling stitches, and a background (ground) of net or bars linking the motifs together. The technique may have developed from straight-sided braids converted to openwork or from the plaiting or knotting of the warp-ends of woven fabrics. The first written mention of bobbin laces dates from 1536 (in the introduction to the Zürich pattern book, printed in 1561) and places their origin in Venice. Their first use in fashion dates from the end of the 16th century, when they imitated and began to compete with the needle lace reticella, already in use for ruffs and other accessories. Two main techniques linked to different geographical areas can be distinguished: non-continuous-thread, in which the design motifs are made first and then joined together by attaching threads around them to work the ground (mainly Brussels, Honiton, and Milanese laces), and continuous-thread, where the same threads work across the lace moving from ground to motif to ground in continuity. Both techniques appear in pattern books of the late 16th century (https://www.britannica.com/art/bobbin-lace). This is a rather simplified description and dating, as the history and evolution of this technique is more complicated to trace. Many books have been written on this topic, some in agreement with one another, some with contradictory opinions, especially on written sources and the land of origin. Spain, Flanders and Italy are all competing for that honour (Palliser 1869, 87; May 1939, 110-111). The most frequently cited source is the Sforza Inventory of 1493 with the sentence *binda una lavorata a ponto de doii fuxi per uno lenzolo* (Cittadella 1863, 532). While most researchers translate the *doii fuxi* as ´two sides´, and argue that no bobbin lace could be produced with only two bobbins (Levey 1990, 10;

Ricci, 1913, 6; van Overloop 1934, 97) the translation ´12 bobbins´ (Italian: 12 = *dodici*) is sometimes given (Lefébure 1904, 261; Verhaegen 1912, 10; Jackson 1900, 14). Jackson even quotes the words as *punti dei dodisi fusi*. It is certainly right that no bobbin lace can be made using only two bobbins. The pattern using the smallest number of bobbins possible is the *Spitzle mit IIII* (lace with four bobbins) in the *Nüw Modelbuoch* of 1561 (R.M. 1561). Moreover, as the word *dodici* is also found in the Sforza Inventory, it does not seem logical that the writer would have used a different spelling for the word 12 in this sentence. Could it be that all that confusion simply originates in an erroneous transcription of the handwriting? Nevertheless, the common conclusion seems to be that bobbin lace developed no earlier than the first half of the 16th century. For that, researchers rely heavily on early pattern books of the 16th and 17th century to chart the development of the art (Waters 2012, 1). This is also thought about the development of needle lace and is based in general on the first pattern books, with the earliest known book, Johannes Schonsperger's *Ein New Modelbuch*, printed in Zwickau in 1524. The oldest pattern books for bobbin lace are the two volumes of the *Le Pompe* published in 1557 and 1560 (Levey 1983). The patterns of Book I consist mainly of geometric, braid-like insertions and relatively few edging laces, while those of Book II include many free-flowing floral and interlaced designs. The quite elaborate vandyked edgings (named for the collars depicted in portraits by Vandyke; with one of several V-shaped points forming a decorative edging or a border of such points) would seem to show bobbin lace at an advanced stage (Levey 1990, 8). Since complex patterns such as these do not spring up overnight, at least some time must have passed since the first bobbin laces were made. The textile collection in the Museo della Basilica in Gandino houses several 16th century laces worked with gold and silver metal thread very similar to the patterns found in Le Pompe (Schoenholzer Nichols et al. 2012, 32-51, cat. 1-22).

Bobbin lace must have found its way up north at a much earlier date than 1557. At the time the *La Pompe* was published lace making had already arrived in Germany. Melchior von Ossa (born 1506 in Ossa, Saxony; died 8 August 1557 in Frauenfels, Thuringia) wrote in 1556: *Itzo findet man wol Weiber und Jungfrauen von Adel… sie lassen theils die Schmuck-Röcke… mit breiten verklöppelten goldenen gezogenen Borten verbremen . . . Ja itzo bringen sie ein neu Verbreme der Schmuck-Röcke auf, das heißen sie Freulein-Geschlingk, daß sie drey quer finger breit golden und silbern Striche klöppeln ...* (Thonhauser 2006, 84; Ossa & Thomasius 1717, 522–523). Not only is the German word for ´making bobbin lace´ – *klöppeln* – used twice, but it becomes evident that these laces were a ´female thing´. Melchior von Ossa wrote that noble women and maidens decorated their gowns with golden borders that they call *Freulein-Geschlingk* (damsel looping).

The second oldest pattern book for bobbin lace, entitled *Nüw Modelbuoch – Allerley Gattungen Däntelschnur*, was published in Zurich in 1561. The author of the *Nüw Modelbuoch*, who is only known with her initials RM (words in the title suggest that it was a woman, since the patterns were intended as instruction for her apprentice girls = *jren Leertochteren*) writes about the introduction of bobbin lace to Switzerland by Venetian merchants ´*Dan die selbigen im jar 1536 erstmals durch die Koufflüt uß Venedig vu Italien ins Tütschland bracht worden*´ (RM 1561). Yet, if the date 1536 is even approximately right, it was not the year that bobbin lace was invented. It must have been common and developed enough in Italy by that time to be considered fit for export by the Venetian merchants.

When looking for more written sources on bobbin lace one encounters the same problem as with the sources on macramé. What was bobbin lace called in its early days? The *Le Pompe* talks about *merli di diverse sorte* (different types of lace) for various uses, and in the *Nüw Modelbuoch*, the German pattern book on bobbin lace, bobbins are called *dentlen* and the lace *Dentelschnüren*. *Dentel* probably derives from the Latin word *dens (*plural *dentis*), meaning tooth, and in the case of lace, something toothed or saw-toothed. Yet, even before the *Nüw Modelbuoch* was published, lace making was referred to as *klöppeln*, the German word still in use today, with the noun *Klöppel* used as the term for ´lace bobbin´. The word *Klöppel* derives from the (East) Middle High German word *kloppen* (= *Klopfer* = beater) and is used to name a rod thickened at one end for striking something, a bell clapper or – due to its similar shape – a lace bobbin. *Merli*, modern Italian *merletto*, translates to lace and the modern word for bobbin lace is *merletto a tombolo* (pillow lace). In French, bobbin lace is called *dentelle aux fuseaux* today, which is related to the Italian *punti dei fusi*, both freely translating to points/lace made with spindles/bobbins. The use of different words at different times and places for the same thing makes it difficult to detect historical sources on almost anything.

Some authors try to date bobbin lace back to the 15th century with the help of paintings or sculptures (Frauberger 1894, 212; Shepherd 2009, 21-36). Rosemary Shepherd admits, however, that she is ´looking at paintings through lace-tinted spectacles´. Indeed, some of the possible bobbin laces in the paintings Shepherd selected are not very convincing. The knotted fringes on the gown in a painting by Bernadino dei Conti, *Portrait of a Lady*, painted before 1525, do look more like macramé than bobbin lace (Shepherd 2009, 34; Levey 1990, 19, fig. 104). A close look at the knotted fringe reveals something like picots, but those can be made in macramé too. More convincing is the lace seen on Andreas Mantegna´s *Presentation at the Temple*, circa 1454, Sandro Botticelli´s *Annunciation*, 1489-1490 and Domenico Ghirlandaio´s *Adorazione del Bambino* before 1494 (Shepherd 2009, 26, 28-29). A painting by Davide Ghirlandaio, *Portrait of a young woman* (Gemäldegalerie Berlin, Inv.No. 83), circa 1490 can be added to the list. The border of her shoulder cloth of transparent fabric seems to be decorated with lace (fig. 16), the pattern is reminiscent of the various *Krönle* patterns in the *Nüw Modelbuoch* and of the lace on the coif from Lienz.

Since most books and articles on the history of lace are written by art or textile historians it might be helpful to gain a new perspective by looking at lace from an archaeological point of view. It is widely thought that needle lace might have begun in the late 15th century and developed over the course of the 16th century (Levey 1990, 1-6). It is debated from whence the *punto in aria* can be considered fully-fledged needle lace (Levey 1990, 6-7). An archaeological find made in 2008 at Lengberg Castle in East Tyrol shows that the beginning of needle lace must be earlier. Four of the textiles found in a vault inside the Castle were adorned with needle lace, with one of the garments, a headdress, being radiocarbon-dated to the first half of the 15th century (AD 1390-1450: ETH-40538: 510±35BP, probability 86.1%). The ties of the headdress, which were still knotted together when the garment was recovered, are connected to the main body of the headwear in two different needle lace patterns, the needle lace sewn onto the selvedges of the fabric of both main body and ties (fig. 17). While this needle lace is far from the elaborate and complicated needle lace of later times, it adheres with the definition of needle lace based on the type of stitches used: lace worked with a needle and a single thread in a succession of buttonhole stitches in varying degrees of tightness and in straight lines that support further stitches (https://www.britannica.com/art/needle-lace). Button hole stitches decorating fabric edges even go as far back as the Bronze Age (Broholm & Hald, 1940 93), but these hardly qualify as needle lace.

If needle lace can be traced further back by archaeology than by consultation of written or pictorial sources the same might be true of bobbin lace. This poses the question from which older technique bobbin lace might have developed. Methods of making decorative braids or laces plaited in various ways, as were most of the early bobbin laces, existed well before the advent of bobbin lace. Possible early connections are loop manipulating techniques such as finger loop braiding, or plaiting with open ends (Shepherd 2009, 1-4). In Europe, loop braiding goes back at least to the 15th century when the first instructions, the 'Treatise on the making of Laces' in the *Tollemache Book of Secrets* (privately owned) and the *Harley* (British Library, MS Harley 2320) were written. Finds from the prehistoric salt mines at Hallstatt (Austria) even suggest that loop braiding might date back to the Iron Age (Grömer et. al. 2015). The similarity between loop braiding and the braids of bobbin lace becomes obvious when comparing the 15th century openwork braid *lace maskell* made with eight loops in the *Tollemache* (Speiser 2000, 65) with a bobbin lace in the Museo della Basilica in Gandino (Schoenholzer Nichols et. al. 2012, Cat. No. 3) and the pattern in the *Nüw Modelbuoch* called *Spärlin gstemlet mit XVI* (R.M. 1561) made with 16 bobbins. Except for the picots of the bobbin lace in Gandino, which cannot be achieved with loop braiding, the lace patterns can easily be mistaken for each other. Three-strand, and especially four-strand, plaiting with open ends bear a great resemblance to early bobbin laces, where braids are made with two pairs of bobbins working together for a simple braid that is then crossed with other braids, just as with the lace edging

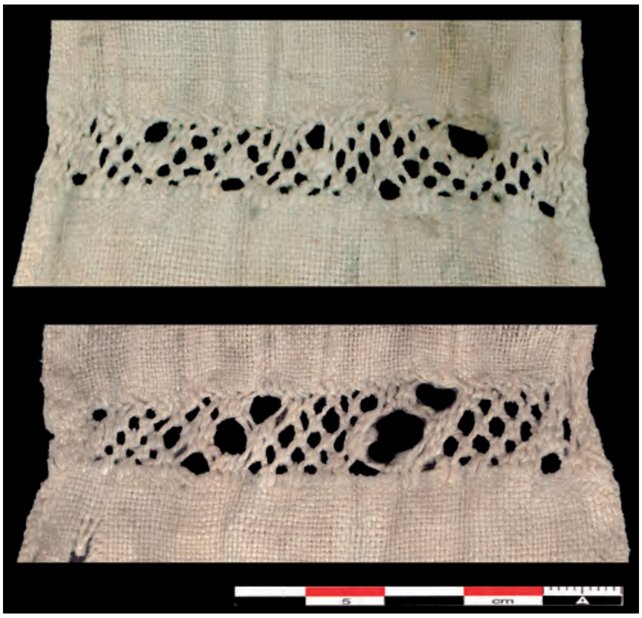

Fig. 17: Needle lace on the ties of the headdress from Lengberg Castle (Image: Beatrix Nutz)

from Lienz, where three times four bobbins are used. Three-strand plaits crossed to make a diamond mesh were found in a layer dating to as early as the tenth century at 16-22 Coppergate, York (Walton-Rogers 1989, 351, fig. 147, 353, 358-359). Instructions for working a four-strand plait with open ends (four strands = *vir vadm*, fol. 19v.) can be found in a German manual of the 15th century among instructions for loop braiding (Badische Landesbibliothek Karlsruhe 1445/1470, fol. 19v-20r; Speiser 2003; Obhof 2004). In this manuscript, loops are called *zwischt*, the term for loop braiding is *schlahen*, and plaiting with open ends is referred to as *flecht*. It is only a small step from loop braiding and open-end plaiting to using bobbins to help organise and manipulate the threads for braids with more strands.

Therefore, it is not too far-fetched to date the coif with the bobbin lace from the tomb of Wolkenstein-Rodenegg to 1509 – or earlier. If bobbin lace developed in Italy, Bianca Maria Sforza might have brought some garments with lace with her to Tyrol when she married Maximilian I in 1498. No bobbin lace seems to be mentioned in the inventory of her dowry (Calvi 1888, 131–147; Sailer 2010, 39–42), but maybe only the more valuable items were listed and lace not made with gold or silver thread was considered less important. Since Barbara von Thun was one of Bianca´s ladies-in-waiting she might have been introduced to bobbin lace by what she saw the queen wearing. It is a nice conceit to imagine Bianca giving Barbara the coif for loyal service.

Extant textiles are a rare archaeological find as the organic matter decays over time. Wood objects, even though likewise organic, have a slightly better chance of survival as they are for the most part not as fragile. Therefore, it is advisable to look into surviving lace bobbins to help date the beginnings of bobbin lace, especially since lace bobbins can also be made of other raw materials such as bone or metal (fig. 18e, fig. 18p and fig. 18q). There is one problem though: there is no guarantee that the first and earliest lace bobbins look like what is now identified and recognised as such. Whoever ´invented´ bobbin lace was faced with the problem from where to obtain the bobbins. Certainly, there were no readily available lace bobbins at the time and the worker would have to use whatever was at hand. That could be simple wood sticks, thread spools (fig. 18j) or even tapestry bobbins. Comparing

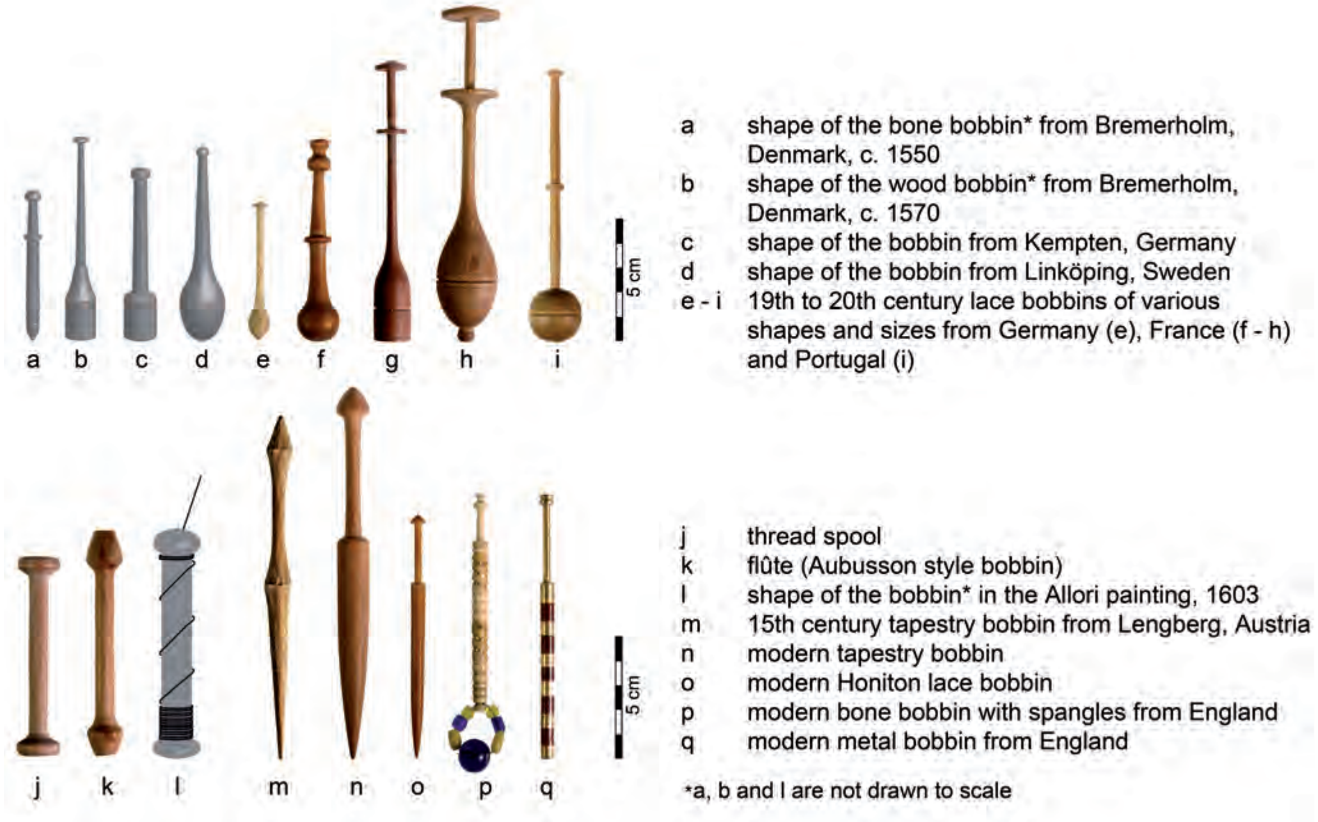

Fig. 18: Thread spools, tapestry bobbins and lace bobbins (Image: Beatrix Nutz; Images: Andreas Blaickner, Institute for Archaeology, University of Innsbruck)

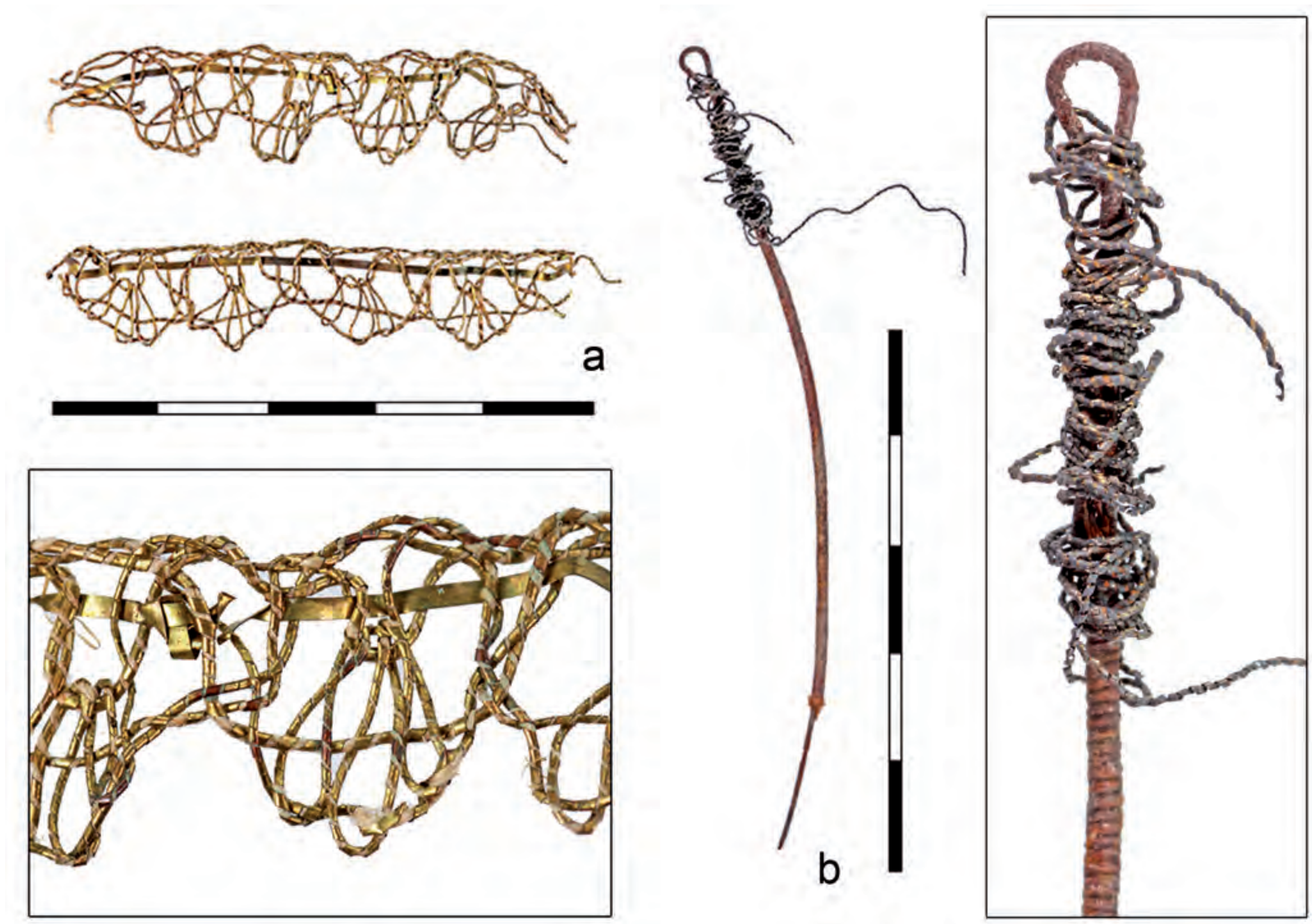

Fig. 19: Bobbin lace: a) and wire with metal thread; b) from the Benedictine Abbey of St John at Müstair, Switzerland (Images: Andreas Blaickner, Institute for Archaeology, University of Innsbruck)

bobbins used for Honiton lace (Palliser 1869, 316–358; Treadwin 1873, 48; Devonia 1875) with tapestry bobbins of the ´broche´ type (Nutz & Ottino 2013, 56) reveals that, except for size, they are of almost identical shape (fig. 18n and fig. 18o). The size and shape of a bobbin however relates to the type of thread and the technique used. Thicker, heavier threads need bigger, heavier bobbins in order to be able to wind on enough thread and provide adequate tension (fig. 18 and fig. 19). The woodcut on the title page of the *Nüw Modelbuoch* shows rather large bobbins employed by the worker, suggesting she is working either with thick (or metal) threads, maybe even using tapestry bobbins. A painting by Allessandro Allori, *Annunciazione*, 1603 (Uffizi Galleries Florence, inventory number 1494), shows bobbins unlike any commonly used (Dahrén 2010, 61, fig. 29). They resemble thread spools or ´flûtes´ of the low-warp tapestry loom (fig. 18k and fig. 18l). This proves that bobbin lace can be worked with bobbins initially serving other purposes. Even in times when lace bobbins are the first choice, a craftsperson might need to use other implements if lace bobbins are not available. This could also result in bobbins hastily made out of whatever is ready to hand. This might have been the case with a tool found in the Benedictine Abbey of St John at Müstair, Switzerland: a wire with a length of 735 mm, bent to a loop on one end and with a thread wrapped tight around the shaft. A gilded silver thread (analysis by Andreas Saxer and Michael Unterwurzacher, Institute of Structural Engineering and Material Sciences, University of Innsbruck, 2013) is loosely wound around the shaft at the end with the loop. The wire was found together with fragments of bobbin lace in a layer dated 1658 to 1659 by the archaeologists and perhaps used as a makeshift lace bobbin (fig. 19b). It even works the other way round. When Kathe Todd-Hooker, a modern tapestry weaver, first started weaving in the late 1970s she did not use tapestry bobbins as they were not available in the United States. She used lace bobbins with small rounded bottoms as substitutes. Other weavers even went as far as cutting off the beads of spangled lace bobbins to make them suitable for tapestry weaving.

Probably the oldest recognisable lace bobbins, aside from the bobbins in the *Nüw Modelbuoch* woodblock print, are depicted on an engraving by Adriaen Collaert after Marten de Vos 1581. A bobbin with a length of 80 mm and of almost the same shape as the ones on Adriaen Collaert´s engraving *The Seven Planets and Ages of Man* was found in Linköping, Sweden, and dated to the time between the end of the 15th century and the later part of the 1550s (fig. 18d) (Dahrén 2010, 58, fig. 26). Among the finds from the Mühlberg-Ensemble in Kempten (Bavaria, Germany) excavated in 1996/1997, are six fragments of linen bobbin lace worked with braids and linen-stitch (Rast-Eicher & Tidow 2011, 317). Additionally a 71 mm long bobbin of sycamore wood (*Acer pseudoplatanus*) with thread (fig. 18c) (Lohwasser 2011, 218 and plate 18, fig. 12) was found in the same under floor space of room seven, house eight, St-Mang-Square. The dating of the finds vary between 15th century until circa 1520/30 for the textiles (Rast-Eicher & Tidow 2011, 285, 343; Atzbach 2011, 357) and 'from the last quarter of the 15th century; nothing more specific can be said about the upper limit of time' for the wooden artefacts (Lohwasser 2011, 240). The coins found in the under floor space accumulate around 1345/1356 (the house was built in 1356), 1424/53, 1549/1557, 1581/1635 and 1661/65 (four coins), close to the heavy ice drift of 1670, which might have caused considerable remodelling in or near room seven (Atzbach 2011, 355-356). Hence, even though Rast-Eicher writes that the finds from Kempten are among the earliest datable bobbin lace (Rast-Eicher & Tidow 2011, 317), no definitive statement can be given about the dating of these finds. Archaeological excavations in Bremerholm in Copenhagen also unearthed early lace bobbins: a small turned bone bobbin dated to 1550 (fig. 18a) and a larger wood bobbin dated to 1570 (fig. 18b) (Tornehave 1987, 17, fig. 3) of a similar shape to the find from Kempten. Taking all of the above into consideration, further research into the history of bobbin lace is required and archaeologists especially should look at finds of textile tools with open minds as to their possible use.

Mixing textile techniques – A short side note

Sometimes the braid-like structure of bobbin lace can be found combined with (macramé) knots. A 16th century bobbin lace in the Leopold Iklé Collection is a plaited diamond net with cushion crossings and picots made with 16 bobbins (eight pairs). In addition, eight gimp threads used double form Josephine knots (Iklé & Fäh n.d., plate 15b; Shepherd 2009, 50). This serves to show that it can be difficult to categorise textiles, even more so if one goes looking for names in different languages and from earlier periods.

Conclusion

The four headdresses excavated in 1968 in the parish church of Lienz reveal the utilization of textile techniques that are surprising considering the early date. Especially the lace decorating the face opening of the coif in particular provides new insight into the development and the spread of bobbin lace. The evidence from this study suggests that knots, today commonly referred to as macramé, were used for more than just knotted fringes, as previously believed. A look at finds from past excavations and old museum collections, which are not yet identified and/or dated incorrectly, forgotten in some depot, might bring more textiles to light and help explain the development of the various textile techniques. It is hoped that future studies investigating written records, pictorial sources and archaeological finds of textiles and textile tools will be able to provide more data and help clarify the rather confusing history of lace.

Notes

1. Regina Bianca (born 1502–died 1539), Elleonora (born 1504–died 1549), Veit (born 1506–died 1538), Catharina (born 1508–died 1568), Anna (born 1509–died 1582), Philipp and Bianca (died juveniles – no dates known) (Mayrhofen n.d., 844).
2. An image of this hairnet haunts the internet falsely labelled as being from Linz, Upper Austria, instead of Lienz in East Tyrol.
3. This painting was copied a lot of times by Bronzino´s workshop and the copy in the Gemäldegalerie Berlin is attributed to Allesandro Allori.

Acknowledgments

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A mysterious little piece:
A compound-weave textile incorporating sea silk from the Natural History Museum, London

Abstract
Sea silk, derived from the beard of the *Pinna nobilis* clam, has often been described in historical sources, but only rarely identified scientifically in extant textiles. This paper describes the microscopy of the fibres in a textile held in the Cuming Collection at the Natural History Museum in London. The textile is a compound weave that incorporates yarns made of sea silk, ordinary cultivated silk and a fine animal coat fibre. The fibres were identified by a combination of transmitted-light, polarised-light and scanning electron microscopy. There is little documentation concerning the origin of the piece, but it is likely to be18th-century Italian and may have come from a waistcoat.

Keywords: Sea silk, *Pinna nobilis*, byssus, compound weave, microscopy, 18th century, waistcoat

Introduction (FM)
For some years now, an almost forgotten textile material has been discussed in archaeological textile research: sea silk, a product of a large species of marine bivalve mollusc, the noble pen shell, *Pinna nobilis* L. (McKinley 1998) (fig. 1). Its antique origin, its rarity, and, above all, its naturally golden-bronze colour made it a subject full of myth and mysteries. A few written sources from antiquity speak of sea silk, mainly in paraphrases or in terms not yet clarified. To this day, only one single fragment from antiquity has been found, in a woman's tomb in Aquincum (Budapest), dated to the fourth century AD (Maeder 2008). A find from Pompeii, originally identified as sea silk, turned out to be an ordinary sponge on closer analysis (Maeder & Médard 2018). The next known sea-silk item is 1,000 years later, dating to the 14th century: a knitted beret found in Saint-Denis, near Paris (for the history and production of sea silk, the biology of the *Pinna nobilis* and its byssus, and an inventory of sea-silk objects, see the project's homepage in English, Italian and German at www.muschelseide.ch).

To date, only two places where sea silk has been processed, at least since the 18th century, have been proven: Apulia and Sardinia, both in southern Italy. Various other places around the Mediterranean are mentioned in the literature (Maeder 2016b), but, as with everything that concerns sea silk, re-telling

Fig. 1: Live specimen of *Pinna nobilis* L., in the sea off Levanto, Liguria (Image: Hechtonichus, Creative Commons Licence 3.0)

of what has been heard or copies of what has been read are frequent. Dictionaries and even professional textile books are also extremely questionable sources (Maeder 2017a). On the small Sardinian island of Sant'Antioco, several weavers still process sea silk for demonstration purposes (Pes & Pes 2017). The raw material used comes from old stock.

Various species of pen shells live in almost all oceans, but the noble pen shell (*Pinna nobilis* L.) is found only in the Mediterranean, where it grows up to 120 cm tall and lives sedentarily in coastal areas up to a depth of approximately 50 m, anchored by its fibre beard in sandy soil and in underwater seagrass meadows. Once very common and sought primarily as food, populations have been declining sharply since the 1950s. The mollusc has therefore been fully protected from over-fishing since 1992. This led to a substantial recovery of the population, but in 2016 it was discovered that a protozoan parasite *Haplosporidium pinnae* sp.nov. was spreading through the Mediterranean and causing mass mortality of *P. nobilis* (Martinovic et al. 2019). The source of sea silk is therefore once more under very serious threat.

The fibre beard, zoologically named byssus, consists of thousands of fine filaments, up to 20 cm long, formed from the secretion of the glands in the foot of the mollusc. These harden on contact with the

Fig. 2: Textile fragment from the Cuming Collection, Natural History Museum, London, turned to a window so that it catches the light (Image: © ASLab)

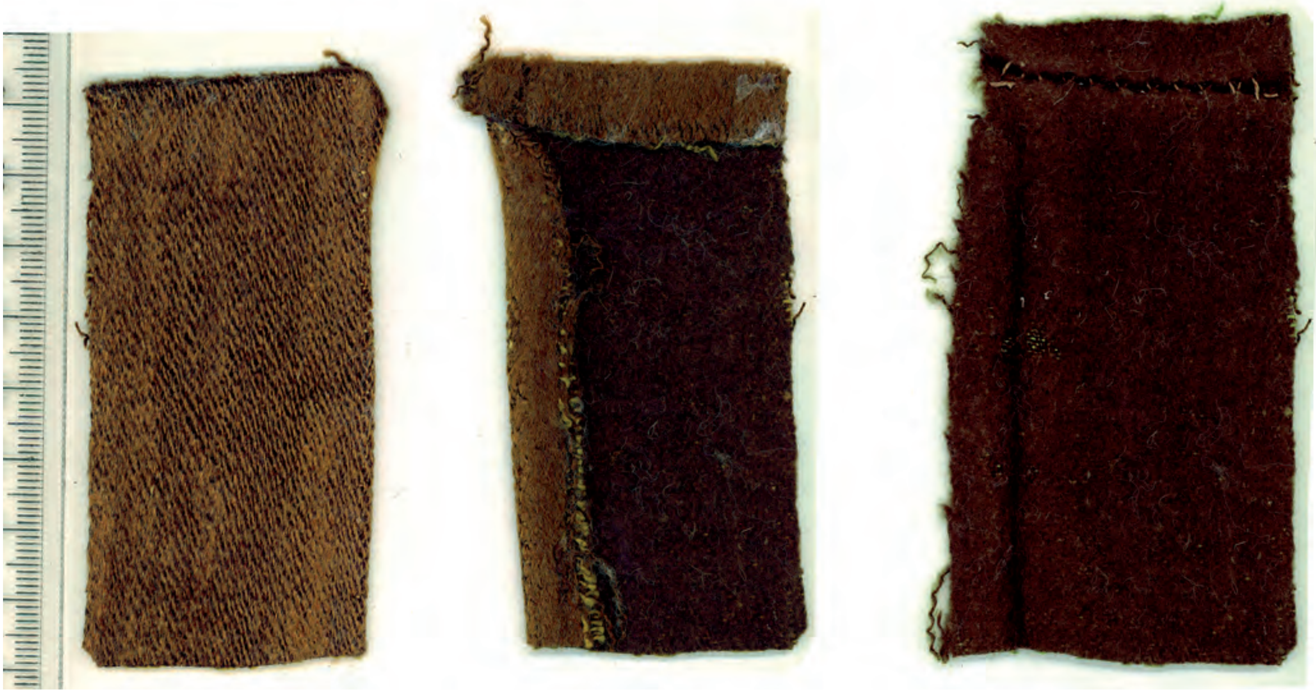


Fig. 3: The whole fragment viewed from the front. Scale in mm and cm (Image: © ASLab)
Fig. 4: The whole fragment viewed from the back. Scale in mm and cm (Image: © ASLab)
Fig. 5: The whole fragment, edges unfolded, viewed from the back. Scale in mm and cm (Image: © ASLab)

water and anchor the shell in the ground with fan-like adhesive surfaces. The shells are brought up whole, for processing on land. The filaments, once removed from the shell, are then cleaned, washed, carded and spun by hand and then made into small accessories.

The Latin term byssus – derived from the Greek βυσσος – meant fine linen in antiquity (Maeder 2017a). The term is known from the *Old Testament*, and also from some Greek texts written on papyri or carved in stone. In ancient Egypt, priests and statues of the gods were dressed in byssus, and mummies were wrapped in it. In the 16th century, natural scientists called the anchor threads of *Pinna* and other bivalves byssus – due to a misinterpretation of Aristotle's *Historia animalium*. Here the double meaning of the term started: since textiles were also produced from the byssus of the noble pen shell, called sea silk, many believed that the term byssus already referred to sea silk in antiquity. The result of this ambiguity is found in many encyclopaedias and, in recent years, especially through mass and social media (Maeder 2016a, 2017a, b).

One of the reasons for the ignorance about this precious material – beside its rarity – is the fact that nearly all of the more than 80 objects identified to date are housed in natural history collections, often displayed together with the shell, and not in textile collections as might be assumed (Maeder 2009). Women's and men's gloves are the most common sea-silk items. Various sea-silk objects can be found in the Malacology Section, Life Sciences Department of the Natural History Museum, London. Beside one pair and two single gloves, there are two pieces of textile: a fur-like one, and one labelled a "small fragment of twill-woven fabric with felt backing". Not much is known about this last item, its date, provenance or function. The annotation "Cuming" refers to the Englishman Hugh Cuming (1791-1865), "Prince of collectors" as he was named by his biographer, S. Peter Dance: "Among 19th-century men of action few contributed as much to the material advance of natural history" (Dance 1980, 477). His main interests were in conchology and botany, collecting especially in South America and the Philippines. After his death, a great part of his collection was bought by the Natural History Museum. The small textile fragment to be described in this paper was one of them (fig. 2).

The textile fragment (PWR)

The textile was provided by the Life Sciences Department of the Natural History Museum (London) for analysis at The Anglo-Saxon Laboratory in York. It arrived in a small cardboard box with an internal printed label which read: "Cloth woven from byssus threads of *Pinna nobilis* □ Mediterranean □ H Cuming Colln. □ Acc. No. 1829 □ Reg.No: 20040207". Inside the box was a single fragment of textile packed in tissue paper. Both faces of the fabric proved to be covered in a "bloom" of white cotton fibres, which suggests that it was packaged in cotton wool at some stage. The textile is a rectangular fragment, measuring 82 mm by 40 mm, with two adjacent stitched edges folded inwards; and two other edges which have been cut (fig. 3 and fig. 4). The folded edges have been turned in by 8 mm to 11 mm and, when unfolded, the fragment measures circa 90 mm to 95 mm by 50 mm (fig. 5). There is silk stitching along the short edge and empty stitch holes along the fold of the long edge.

The textile is 1.5 mm thick and, since front and back are visually quite different, it gives the impression of two textiles layered together. Examination with a binocular microscope at x 10 magnification, however, showed that it is in fact a compound weave which has been "soft-finished" on the back. It was made from yarns of three different fibres, sea silk, ordinary silk (from *Bombyx mori*) and a very fine animal coat fibre (see below). The exact structure of the weave could not be determined, due to the heavy matting of fibres, but it is some form of double-faced twill, with the silk yarn running in one direction and the sea silk and animal-fibre yarns in the other. The sea silk dominates on the

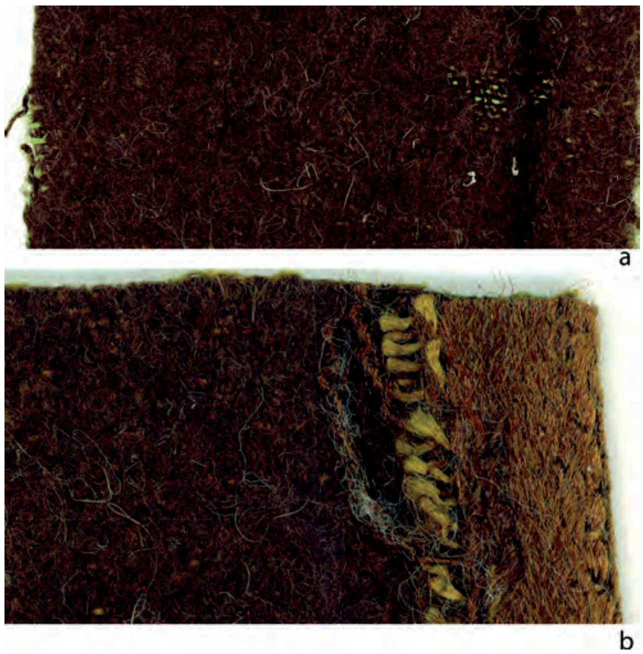


Fig. 6: a) Close-up of back of textile showing crossways silk yarns; b) Close-up of folded-back edge of textile, showing crossways silk yarns. The white fibres adhering to the surface are cotton (Images: © ASLab)

front of the fabric and has the appearance of a long velvet-like pile, although, since the textile is very worn, it is possible that the apparent pile in fact represents the broken stumps of a floating yarn. The animal fibre dominates on the back and has been "soft-finished" to give a felt-like appearance. The *Bombyx* silk yarn, only visible at the cut edges and in worn patches on front and back, binds the sea-silk and animal-fibre yarns together (fig. 6a and fig. 6b).

This, then, can be summarised as a twill-based compound weave with a soft-finished reverse. All yarns are Z-spun and single. Counting threads accurately was difficult, but there appeared to be approximately 24 sea-silk yarns and 12 silk yarns per cm. The animal coat fibre yarns could not be counted but they are at least as densely set as the sea-silk ones. The sea silk is light golden brown, the silk is its natural pale straw colour, but the animal coat fibre is an even mid-brown and may have been dyed.

The stitching

The stitching visible inside the short folded end has been worked in plied silk yarn, twisted Z2S (i.e. two Z-twist yarns have been plied together in the S-direction), circa 0.6 mm thick (fig. 7). It appears to have been dyed red, although it would be impossible to sample it without causing damage to the integrity of the piece. The stitching looks to be the remains of a running stitch, which will have attached this piece to another element. The stitch-holes along the longer edge represent the remains of a similar seam. Together, they indicate that the fragment has come from a garment or soft furnishing.

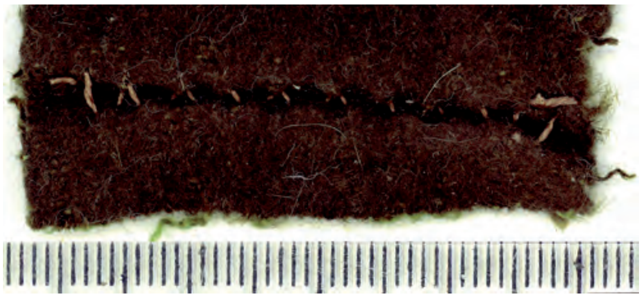


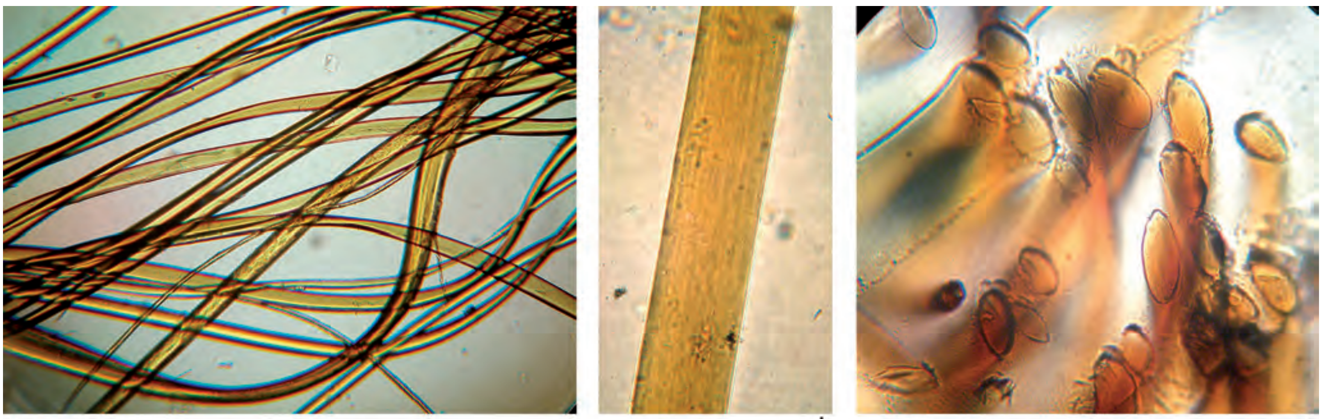
Fig. 7: Close-up of silk stitching along short edge, viewed from inside. Scale in mm and cm (Image: © ASLab)

Fibre identification

Samples of 50 to 80 fibres from each of the three yarns and the sewing thread were removed with tweezers. They were mounted on glass slides in tap-water and examined first with a microscope that has incident light at magnifications between x 40 and x 160; transmitted light at x 40 to x 640; and a measuring facility in the form of an eyepiece graticule at x 40 to x 400 (pre-calibrated with a stage micrometer). The mount was then viewed with a polarised light microscope which uses transmitted light at x 40 to x 400 and a rotating stage. Cross-sections were prepared in an acetate-based medium, sliced with a hand-held razor and viewed with the same microscopes.

Sea silk

The distinctive glistening fibres of the yarns that dominate on the front face, under the microscope were clear, plain and wide (fig. 8a). Diameters recorded



a b c

Fig. 8: a) Fibres extracted from the sea-silk yarn, viewed with a transmitted-light microscope. Note how the wide filaments appear narrow when viewed from the side. Image captured at x 40 magnification with camera zoom. Range of fibre widths in this image, 35 microns to 62 microns; b) A single fibre extracted from the sea-silk yarn, viewed with a transmitted-light microscope. Image captured at 100 x magnification, with camera zoom. The fibre is circa 60 microns wide; c) Cross-sections of fibres extracted from the sea-silk yarn, viewed with a transmitted-light microscope. Image captured at 100 x magnification with camera zoom. The fibres are in this image are 22 microns to 63 microns wide (Images: © ASLab)

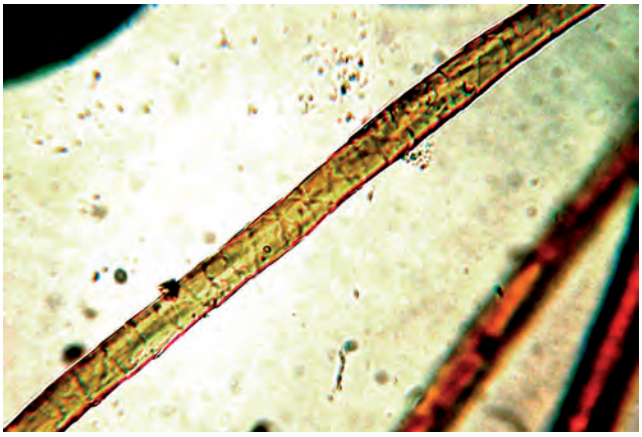


Fig. 9: A single fibre extracted from the animal-coat-fibre yarn, viewed with a transmitted-light microscope. Image captured at 100 x magnification and digitally enhanced to improve the poorly preserved scale pattern (Image: © ASLab)

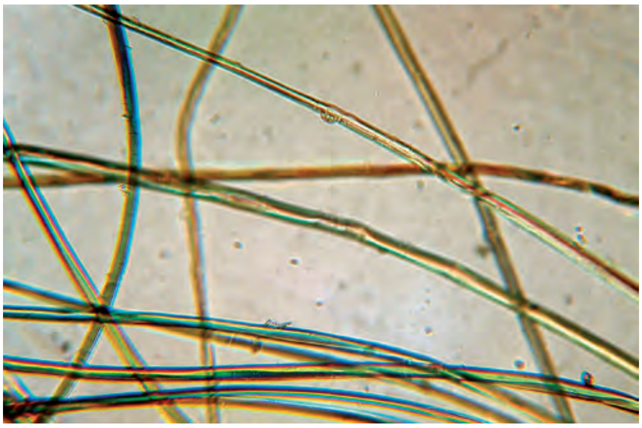


Fig. 10: Fibres extracted from the *Bombyx* silk yarn, viewed with a transmitted-light microscope. Image captured at 40 x magnification, with polariser inserted (© ASLab)

for 56 fibres ranged from 22 microns to 63 microns (mean 38.3±9.6, mode 37, median 37.1, symmetrical distribution). This can be compared with the range of 10 microns to 60 microns reported by Sicken (2017, 23). The absence of measurements below 20 microns in the current examination may result from the measuring procedure, which allows a view of the full length of the filament and to reject wide flat fibres which have rotated to present a thin sideways view. Very fine lengthways markings were visible at high magnification, but apart from this there were no internal or external features (fig. 8b). The fibres were dark when viewed with polarised light, with very little brightening as the stage was rotated. The cross-sections were uniformly elliptical (fig. 8c) (as recorded in Sicken 2017, fig. 3.4).

Fig. 11: SEMicrograph of the sample, Z-twisted thread (Image: © Margarita Gleba)

Elliptical cross-sections are also found in the fur of aquatic mammals such as the harbour seal, although those fibres have an additional pattern of overlapping scales in the cuticle (Appleyard 1978, 24-5, 105-6). The ends of the sea silk fibres were fractured and splintered, probably from wear. As this was an important finding, a sample of yarn was passed to Margarita Gleba for Scanning Electron Microscopy (SEM) and comparison with a modern specimen (see below).

Animal coat fibre

The fibres of the soft-finished reverse of the textile had the remains of a cuticular scale pattern which indicated that they were animal coat fibres such as wool or cashmere (fig. 9). Much of this scale pattern had worn away and there were many "brush end" fibres, indicative of extensive wear. The damage meant that the fibre could not be identified by species, although the very narrow diameter range of 12 microns to 17 microns would be consistent with cashmere, or perhaps fine wool extracted from sheep's fleece by some process such as combing. No pigmentation granules were present, indicating that the original (inherent) colour of the fibre was a natural white.

Bombyx silk

The fibres of the crossways yarn (fig. 10) were smooth and fine, 9 microns to 11 microns wide, with no visible internal features, and they had triangular cross-sections. The dominant colour when the polariser was rotated was blue. These features indicate degummed silk from the cocoon of the silk moth, *Bombyx mori* (Textile Institute 1975, 12-13, 69-71). There were no particular indications of wear in this yarn.

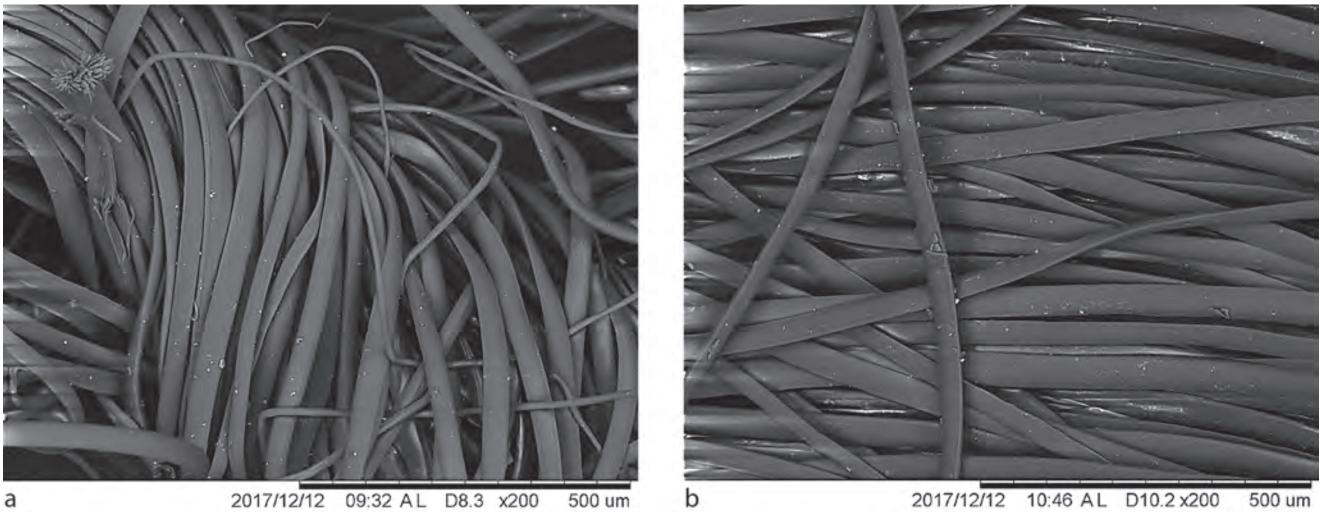


Fig. 12:.a) SEMicrograph of the fibres showing smooth surface with some longitudinal striations; the finer fibres mixed in at irregular angles are fine animal coat fibres, probably from the one of the other yarns in the textile; note the fractured and splintered fibres in the top left; b) SEMicrograph of modern sea-silk reference sample (Image: © Margarita Gleba)

Sewing thread

The fine filaments of the sewing yarn were also degummed *Bombyx* silk, as described above, although they were more irregular in profile and had some fine fibrils emerging from the fibre walls, which suggests either a low-grade silk or perhaps intense wear (Textile Institute 1975, fig. 42). This yarn appeared to have been dyed red.

Cotton contaminants

The white fibres adhering to front and back of the textile were identified as cotton (from the seed boll of *Gossypium* sp), from the twisting nature of the fibres, the prominent lacunae and the presence of fine spiral markings, which were only visible when the polariser was inserted and rotated (Textile Institute 1975, 14, 74-75).

Scanning Electron Microscopy (MG)

Further work on the sea silk fibres was carried out at the McDonald Institute for Archaeological Research, University of Cambridge. The sample was analysed using a Hitachi TM3000 TableTop Scanning Electron Microscope (SEM) in order to determine the morphological characteristics of the fibre and to acquire more detailed surface information for fibre identification. The following instrumental settings were used: analytical condition mode at 15.00 kV accelerating voltage, compositional imaging and working distance of 5 mm to 10 mm. The sample was not coated. The observed features were compared with the author's reference material of sea silk fibres, obtained from an Italian handweaver, Assunta Perilli. When observed in the SEM, the sample was a tightly Z-spun thread (fig. 11). The fibres are somewhat ribbon-like, with two broad and flat surfaces and two slightly rounded edges; they have a smooth surface with occasional longitudinal striations (fig. 12). Fine animal coat fibres are mixed in at irregular angles and probably derive from one of the other yarns in the textile (see above). Some of the fibres are fractured and splintered, likely due to wear. The flat, somewhat ribbon-like appearance of the fibres is due to their elliptical cross section (fig. 13). The diameters of 25 fibres measured a range between 11.3 microns and

Fig. 13: SEMicrographs of fibres showing an elliptical cross-section (© Margarita Gleba)

Fig. 14: Textile sample from a pattern book, "Feine Gewandschaft", dated to 1800, Monschau, Germany (Image: © Felicitas Maeder)

44.6 microns, with a mean of 27.2 microns and median of 26.6 microns. Rast-Eicher (2016, 286) provides a range of 10 microns to 30 microns for sea silk fibre, while Sicken (2017, 23) gives a broader range between 10 microns and 60 microns. All morphological characteristics of the sample demonstrate close similarities with the sea silk reference sample, which had a fibre diameter range of 11.5 microns to 52.4 microns (fig. 12b).

Conclusion (FM)

The London sea silk fragment has a twin, equally enigmatic: a small piece of fabric from a pattern book dating to around 1800, found in the once famous textile town Monschau, near Aachen in the Rhineland (fig. 14) (Maeder 2013). There was no possibility to analyse this sample from both sides, but the presence of sea silk fibres on the front has been proven (Sicken 2013). The use of sea silk in the 18th century is also known from textile entrepreneurs in Normandy (France). Such showpieces have been presented at exhibitions and fairs and offered at unbelievable prices. The *Journal de l'Empire* describes a cloth of extraordinary brilliance and beauty at the price of 500 francs for one ell (circa 70 cm) (Malte-Brun 1806). In a French textile dictionary of 1857, it reads: *"L'échantillon … dans lequel la soie de pinne-marine ne fait que le poil, c'est à-dire l'endroit du tissu, a l'aspect d'une peau de bête, d'une grande finesse, telle, par exemple, que le poil de castor"* (Bezon 1857, 316-317).

What were these two fragments used for, as thick and inflexible as they seem? Arabic texts of the 11th century tell about the *bukalamun* (besides *suf-al-bahr*, a possible Arabic term for sea silk), "a fabric with changing colours, used for saddle-cloths and for covering the royal litters" (Smith 1890; Dimand 1930; Maeder 2017c). From 18th-century travellers in southern Italy, however, it is known that sea silk was used for waistcoats (von Salis-Marschlins 1795, 509) and the luxurious fabrics for waistcoats from Monschau were famous and greatly in fashion at the time. More than 100 years later, the Florentine photographer, Vittorio Alinari, reports sea silk manufacturing in Sardinia. He speaks about a beautiful textile, used also for waistcoats: *"…una stoffa di un bel colore metallico, che si avvicina al rame, con la quale si confezionano delle sottovesti che, guernite di bottoni in filigrana d'oro, pure lavorati nel paese e nel Cagliaritano, producono bellissimo effetto…"* (Alinari 1915, 114). A waistcoat therefore seems a likely source for this piece.

Almost half of all items documented in inventories as sea silk are knitted (mostly plain, sometimes patterned). There are also crocheted objects, fabrics with woven or embroidered sea silk ornament and fur-like objects with a pile made of cleansed fibre beards. Besides the two woven textile samples presented here, only one woven scarf has been recorded. There are many questions to be answered about the origin and use of these pieces and much research remains to be done. Any future studies, however, should incorporate the identification of fibres by microscopy, as described in this paper.

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Johanna Banck-Burgess

THEFBO
The cultural-historical importance of textile production in the prehistoric wetland settlements

Introduction
THEFBO – "The cultural-historical importance of textile production in the prehistoric wetland settlements on Lake Constance and Upper Swabia - in the context of the requirements for textiles: objective and perception" is a co-operation project within the funding framework of "The Language of Objects - Material Culture in the Context of Social Development" from the Federal Ministry of Education and Research in Germany. This funding framework offers a great opportunity for collaboration between a range of faculties and disciplines, addressing various cross-cutting issues and integrating archaeological objects in archaeometry, conservation work, modern textile research, experimental archeology and museology. Only with the involvement of all these faculties can the full potential of textiles in wetland archeology be fully unfolded. The potential is there for understanding the key elements of textiles in the cultural historical context of these settlements in southern Germany, an understanding that may likewise change the perception of early arable crop farmers locally and even internationally.
The project will run from September 2018 until August 2021. It is coordinated by the Department of Textile Archaeology at the State Office for Cultural Heritage Baden-Württemberg in Esslingen. The partners are The University Erlangen-Nürnberg, the Archaeological State Museum Baden-Württemberg in Konstanz, the Curt-Engelhorn-Center Archaeometry GmbH in Mannheim and the University of Würzburg.

Pile-dwelling settlements – early textile production
Pile-dwelling settlements have so far been documented around the Alps, e.g. the lakes and bogs in and around Switzerland, eastern France, northern Italy, Slovenia, Austria and south-west Germany, and they belong to the most important prehistoric discoveries in Europe. These important and unique groups of well-preserved settlements were placed on the UNESCO Cultural World Heritage list in 2011, thus confirming the significance of these outstanding sites that have an abundance of archeological material.
A significant amount of pile-dwelling settlement research has taken place in Baden-Württemberg, where some large-scale, interdisciplinary projects have been in progress since the 1970s. These projects, in cooperation with the State office for Heritage Management and Archaeology and with universities and museums, have all played an important role in the gathering and archiving of material from these sites (Pfahlbauten 2016) (fig.1). In Switzerland, as well as eastern France, textile fragments from numerous well-preserved sites have been excavated and published (e.g. Bazzanella et al. 2003, Médard 2010, Rast-Eicher & Dietrich 2015). Only a small percentage, however, of the data on textiles of the south German wetlands has so far been published (Körber-Grohne & Feldkeller 1998, Feldtkeller 2004; Banck-Burgess 2015).

The primary focus of early textile production research has most often been the weaving perspective and the introduction of flax fibers. This perspective is decisively influenced by the modern perception of textile production techniques. It often places too much emphasis on the production aspects of weaving that required mechanical facilities and was classified as "höhere stoffbildende Techniken", in contrast to the main textile techniques of prehistory that wereclassified as "primäre stoffbildende Techniken"

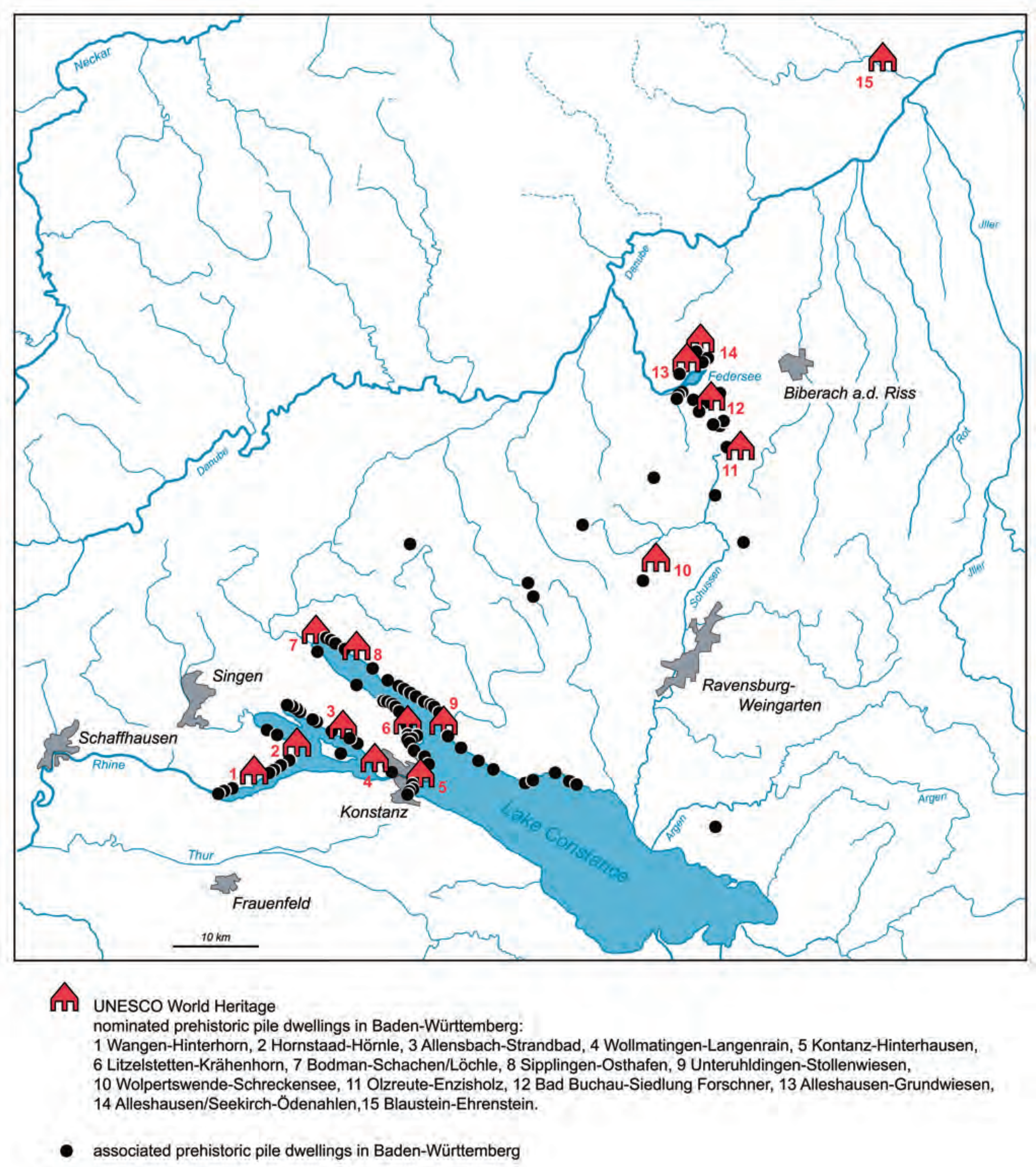

Fig. 1: Pile dwellings in Baden-Württemberg (Image: Yvonne Mühleis, State Office for Cultural Heritage Baden-Württemberg in Esslingen)

(Seiler-Baldinger1991). The history of linen is often referred to as part of a prehistoric revolution that had its origins in the Near East (Karg 2015). The main thesis in this project, however, aims to illustrate the significance of textile fibers and their manufacturing process with the context of the early agrarian settlements. There are five hypothesis that are being followed:

1: The contemporary manufacturing textile techniques that are present at the Neolithic Lakeside

Fig. 2: Sieve; twine binding; pile dwelling Sipplingen (Image: Yvonne Mühleis, State Office for Cultural Heritage Baden-Württemberg in Esslingen)

settlements around the Alps were already in use during the transition to early domestic lifestyle. The knowledge of techniques in use stems directly from the previous hunter-gatherer cultures. By researching and establishing exactly how these techniques and processes came into being, it should become possible to demonstrate the astounding efficiency and the close symbiosis between different production techniques and the more specialised processing methods of textile fibers. It may likewise become clear that there were no multifunctional textiles in the early Neolithic society but instead specifically made objects that were adjusted to fit the precise function. These technical textiles could well have been normalized standards but still have had certain textile characteristics that point towards a specific adaptation of their functions (fig. 2 and fig. 3).

2: The extraction, transformation process and production of tree bast fibres, including the portable production of mesh fabrics, braids and warp fabrics for two and three dimensional textile objects, had reached a high level of production during the early Neolithic culture. Although the flax fibre for woven textiles was already well established there seems not to have been a sudden or enormous requirement for this production.

3: Flax fibres in their earliest usage are primarily found within the context of fishing. The design of finely produced flax fibre fishing nets generated a significant increase in the catch spectrum for the Neolithic people.

4: While technical textiles were important for the early farmers they were less important towards the end of the Neolithic culture with the transition to metal-bearing cultural groups. In this time, referred to as shifts in socio-political culture, it seems that woven textiles i.e., with large, two-dimensional scale increased. The woven fabrics were primarily used for clothing and textiles that had a social significance. This response is linked to the convenience of different weaving facilities such as the warp-weighted loom. Wool, at the end of the fourth millennium began slowly to gain importance in Central Europe, and may have had a significant role in this context. This change might emerged by a change in the requirements of textiles, a shift in the perception of textiles and therefore their production.

5: An increase in large-scale fabrics at this time also led to a loss of knowledge, namely the extraction and processing of tree bast fibres. This in turn led to a decline in textiles from tree bast fibres. In this context the storage basket largely replaces the range of different, individually produced vessels, containers and other technical textiles.

The archaeological material

These five hypothesis are being carried out on textile complexes from well documented wetland settlements around Lake Constance and Upper Swabia. There are over 1700 objects, the majority of which are stored in the state archives of the Archaeological State Museum Baden-Württemberg in Rastatt. The textiles from the Neolithic settlement of Hornstaad -Hörnle IA (dated BC 3917-3902) is unique with more than 1200 objects. No other Neolithic wetland settlement in Europe has yielded such an extensive amount of textiles covering such a short settlement period (fig. 4 and fig. 5). Many other outstanding wetland textiles are currently stored at the Landesmuseum Stuttgart, Rosgartenmuseum Konstanz, Tübingen University Collection, Hohenzollern Collection in Sigmaringen, the Reiss-Engelhorn Museums in Mannheim or are exhibit in the Archaeological State Museum in Konstanz. Only a small number of these finds has been published so far: about 100 objects from Hornstaad-Hörnle IA (Körber-Grohne & Feldtkeller 1998), about 30 objects from Seekirch-Achwiesen (Feldtkeller 2004), a comparable number of textiles from Degersee in Upper Swabia (Banck-Burgess 2015) or as isolated finds from Bodmann-Schachen (Köninger 2006). The research results are concentrated in a databank especially for this purpose.

Research priorities

The vast majority of textiles from the pile dwelling were produced from tree bast, especially lime bast. In the ethnographic literature, there is very little information found regarding its extraction process, its treatment and processing methods. This has already been addressed (Harris et al. 2017). Research on lime-bast fibers will be carried out within the framework of the project but driven by research in paleo botany, modern fibre research, textile archeology and hence demonstrate the potential of this raw material. Interdisciplinary research of individual textile groups, such as on ropes or stitched bark containers, combined with experimental archeology should emphasis their outstanding and versatile usage in everyday life of the farming settlements (Banck-Burgess 2017). A compilation of European textile finds from the Mesolithic culture is intended to show to what extent the conditions for such a high-end textile trade already existed in Mesolithic Central Europe.

Cooperation between the research partners and practice partners, and the division of tasks

A comprehensive survey and analysis of wetland textiles is taking place in the central archaeological archive of the archaeological Landesmuseum in Rastatt. This is accompanied by the wetland archeology of LAD in Baden-Württemberg with regard to evaluation of finds. The design and development of a suitable database ensures that these important finds are also accessible to future research. The functional classification of the sewn bark container and coiled baskets should be supported by the study of the food and remaining residues, which will be carried out at the University of Tübingen/Archaeometry. The practical usage of coiled baskets and bark containers will be based on results from experimental archaeology at the University of Exeter. The collections of ropes and cords are examined at the University of Nürnberg-Erlangen. They should be examined in accordance with their expected functional use within pile-dwelling constructions, the transfer of heavy objects, and binding of different objects. Theoretical consideration on the amount of raw materials necessary for textile production, especially the need for tree bast fibers, will be sketched out. In order to make optimal and sustainable use of the knowledge resulting from the project, in particular concerning the research and identification of lime bast fibers and lime bark, two of the THEFBO partners, the archaeometry center in Mannheim (textile research) and the Dendrology/Palaeobotany of wetland archeology at the LAD (Hemmenhofen) are to share a position. From Mannheim, material tests by the German Institute for Textile and Fiber Research (DITF) in Denkendorf, will be coordinated. These tests will be based on samples from experimental archeology to determine material properties of lime bast and flax fibers. In order to assess the potential of limebast at different stages of preparation and processing, partners working together at the University of Erlangen and ALM will carry out an investigation of production techniques. An important partner in this joint project is the museum's specialist at the University of Würzburg.

The opening of a small exhibition at the Federseemuseumis part of a workshop in June 2020. An Internet forum is already developed for the purpose of becoming an intensively used portal for providing up-to-date information that can be exchanged between all partners during the span of the project. This forum will allow a closer and more immediate communication between individual specialists. A webside (www.thefbo.de) provide the public with information about the project.

Conclusion

THEFBO's vision is to prove that the transition to settled communities within early farming culture

Fig. 3: Part of a back carrier; pile dwelling Hornstaad-Hörnle IA (Image: Yvonne Mühleis, State Office for Cultural Heritage Baden-Württemberg in Esslingen)

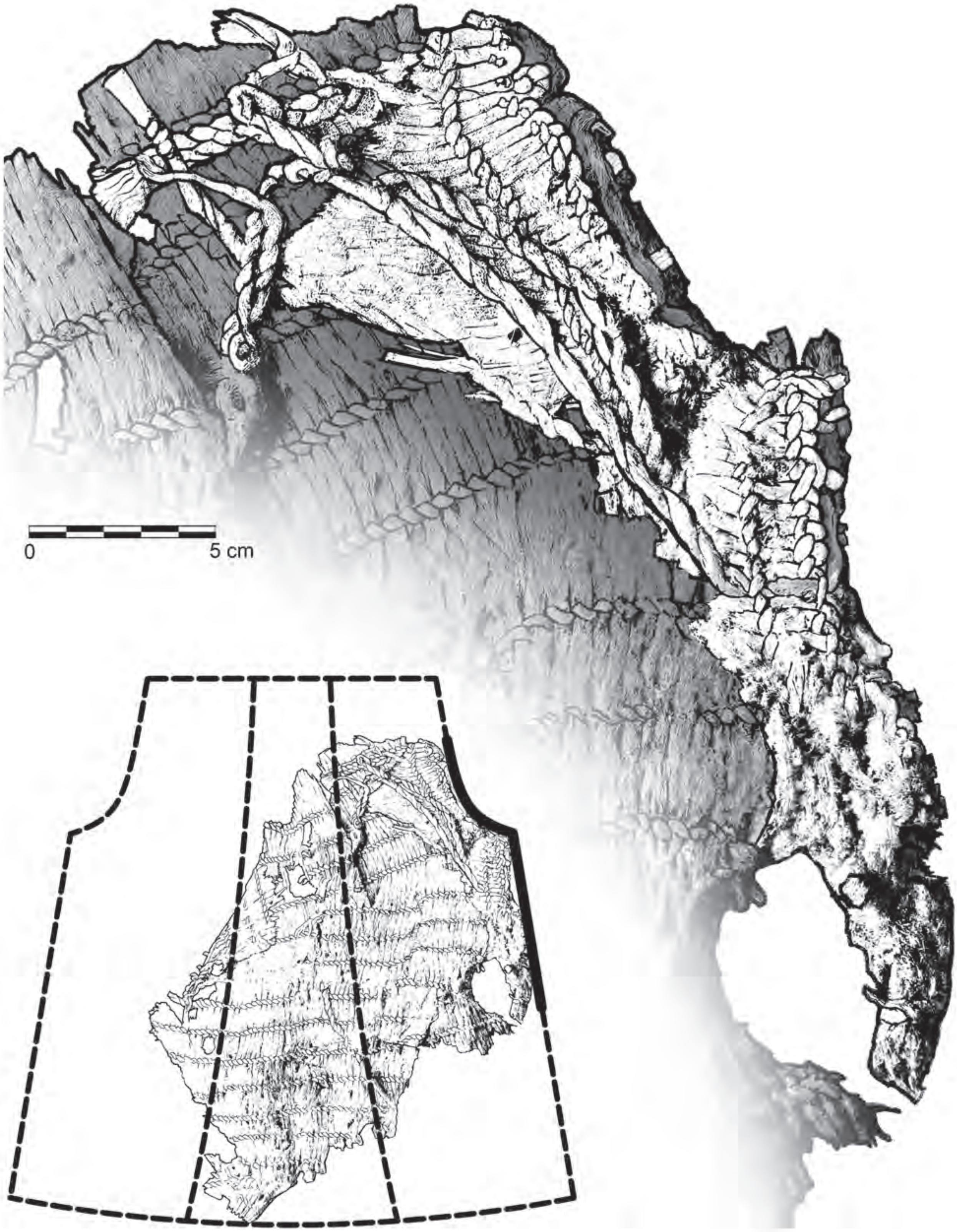

Fig. 4: Fragment of a piece of clothing; pile dwelling Hornstaad-Hörnle IA (Image: Christina von Elm and Johanna Banck-Burgess, State Office for Cultural Heritage Baden-Württemberg in Esslingen)

Fig. 5: Stitched bark container; pile dwelling Sipplingen (Image: Yvonne Mühleis, State Office for Cultural Heritage Baden-Württemberg in Esslingen)

was largely determined by textile production. In this collaborative project, the research team will use textiles artifacts to demonstrate a new and exciting perspective of early agriculturally-oriented settlements. The aim is to show that these settlements were essentially shaped by textiles, in their daily livelihood, their cultural self-understanding and their cultural-historical development up to the Bronze Age. The interdisciplinary group of scholars from textile archeology, palaeobotany, archaeometry, fiber and textile research, experimental archeology and museology will pursue not only the main research areas, but also with the intention of supporting and strengthening textile archeology as an academic discipline and bring the results to the attention of a wider public.

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Friederike Hertel and Karina Grömer

Project reassessment of iconic textiles at the Halle Museum:

New dates and fibre analysis for Ditfurt, Latdorf and Unterteutschenthal

Early textiles at Halle Museum and their importance in archaeological research

In the second half of the 19th and the first half of the 20th century, some important Stone and Bronze Age textiles were found which have since been stored at the Halle Museum an der Saale in Germany. In 1959, Karl Schlabow published those finds with methods and technical tools based on the best knowledge at the time. Archival material stored at the museum explains that he also aimed to use microscopes to undertake "micro-investigations" on the finds from Unterteutschenthal (Schlabow 1956).

Since then, the finds were of importance for our understanding of early textile culture in this area. The artefacts from Kreienkopp near Ditfurt and Spitzes Hoch near Latdorf were interpreted as being among the oldest wool finds in Germany and the textiles from Unterteutschenthal are thought to be important Early Bronze Age finds. Throughout the 20th century, they served as the missing link between the textiles from the lakeside findspots around the Alps, especially in Switzerland, and the well-known textiles from the oak coffin graves in Denmark from the Early Bronze Age.

In recent decades, the availability of radiocarbon 14 (C14) dating and scanning electron microscopy (SEM) for fibre analysis brought new opportunities to early textile research that were not available to Schlabow. This prompted Halle Museum an der Saale to start a project to re-assess these important finds. Some interesting new results concerning the date and raw materials of the finds from Ditfurt, Latdorf and Unterteutschenthalare are available.

Fig. 1: Neolithic textile from Latdorf, now at Halle Museum, with detail of the silver-painted plate (Images: Friederike Hertel, LDA)

Fig. 2: Textile finds (Ditfurt-90) from the excavation season at the Kreienkropp tumulus II in 1990 (Image: Friederike Hertel, LDA)

Neolithic "wool" textiles from Latdorf and Ditfurt

Three textile complexes from Latdorf and Ditfurt were found in the large Bernburger Culture tumuli. This was a late Neolithic culture located in today's Sachsen-Anhalt and Thuringian basin between 3200 and 2800 BCE.

The textiles from Latdorf (inventory number HK-Nr. 57:97) were excavated in 1880 by Friedrich Klopfleisch (then professor for prehistory at the University of Jena) at the tumuli site of Spitzes Hoch. The artefacts recovered in this excavation were divided between the Halle Museum and Museum Schloß Bernburg. The textile finds have never been exhibited, but the Museum Bernburg has plans to include these early textile finds into renewed displays in future.

After the excavation at the beginning of the 20th century, the charred textile fragments from Latdorf underwent conservation treatment, which included gluing them to cardboard to preserve and hold the charred items together. A cellulose nitrate (possibly *Zaponlack)* was also used. The area of the cardboard not covered by the textiles was painted with a silver colouring (using Aluminiumbronze pigment) in a careless way which partly overpainted the textiles (fig. 1), as previously documented by Schlabow (1959, 102). In addition, some smaller fragments were pressed between two glass plates, which was a technique in the conservation of archaeological textiles in the mid-20th century (Grömer & Reschreiter 2013, fig. 11).

The Neolithic Ditfurt textiles that are well known in the academic community are those from the Kreienkopp I tumulus (Ditfurt-33: HK-Nr. 57:94). These were excavated by Karl Schirwitz in 1933 (Hertel & Schlenker 2018, 44-48). The finds were taken to different museums, as was common in the first half of the 20th century. Some fragments are kept at the Halle Museum and other parts of the same textile are stored at Schlossmuseum in Quedlinburg pressed between glass plates to preserve them. One of the plates is kept in Quedlinburg and two are in Halle.

In addition to these well-known finds (Schlabow 1959), new excavations in 1990 brought to light further textile samples. The Kreienkopp II tumulus near Ditfurt was excavated by Detlef Müller in 1990 and mentioned in his excavation reports (Müller 1992a, 221-232 and 1992b, 21-32). The textiles were found in the western section of the burial chamber, along with charred seeds of various wild plants, such as *Cynoglossum officinale, Fallopia convolvulus, Amaranthaceae, Agrimonia L.* Some of these are medical and dye plants. The textiles may have served as a bag for storing the plants. In the same area, charred human bones were deposited, along with a large quantity of pottery (some undamaged), various antler tools, and dog and fox teeth used as a necklace. Animal bones from rodents, cows, pigs and fish were also found in a charred state. They had burnt on a pyre together with the corpse (Müller 1992b, 22).

For the first preservation treatment in 1990, the textiles were cleaned with ethyl alcohol and stabilised with the polymer Scopacryl D 343. They were glued to glass plates for storage (fig. 2). Some of those newer finds are now included in the permanent exhibition of Halle Museum and published in detail in a catalogue (Hertel 2020). All textiles from Ditfurt were investigated during 2007 and 2008 as part of the preparation of the new permanent Neolithic exhibition at Halle Museum, including fibre analysis using environmental scanning electron microscopy (ESEM) in cooperation with the German National Criminal Investigations Bureau in Magdeburg.

Fig. 3: Details of the textile from Latdorf (Halle) with plied thread and ESEM image of the fibres (Images: left and middle Friederike Hertel; right Uwe Schwarzer, German National Criminal Investigations Bureau, Magdeburg)

Fibre analysis

Schlabow studied the charred textiles from Latdorf and Ditfurt when they were still glued to cardboard and with limited analytical methods (Schlabow 1959). He assumed that the raw materials are sheep's wool. Recent SEM analysis now shows the fibres to be of plant origin. Those from Latdorf were assessed using transmitting light microscopy (TLM) and SEM. The characteristic nodules (fig. 3, right), which distinguish plant fibre material from animal hair fibres with scales, are clearly visible using SEM.

Similarly, analysis of the Ditfurt material with SEM successfully identified characteristics of plant fibres (fig. 4, right), without being able to specify whether they are the plant fibres from flax or hemp. Comparison with similar contemporary finds suggests flax is likely. The results of those analyses were published together with a reassessment of the contexts and the research history (Schlenker & Hertel 2018).

Reassessment of technical data

All the textiles found in the tumuli of the Bernburg Culture at Latdorf and Ditfurt are fragmented and charred but their weave structure, quality and technical details are comparable. Thanks to the latest conservation work, reanalysis of the technical details was possible and additional information about the construction of the threads was undertaken.

Several charred fragments from Spitzes Hoch at Latdorf are fine tabby textiles which may belong together, as they show the similar characteristics such as comparable thread counts and thread qualities. The textile is characterised as an open weave (fig. 4, left). In some fragments, a densely woven starting border is also visible (fig. 5, left). In this border, the thread count is 10 threads per cm as is that of the warp in the main weave with 28 threads per cm in the weft. The textile is balanced with the same kind of thread from a plant fibre been used for the warp and the weft. In some parts of the textile, the characteristics of spliced thread are visible, such as changes in the intensity of plying (fig. 5, right). The technical details of the weave are given as an average because there is some variety in the thread diameter and thread counts. The warp comprises 0.3 mm to 0.4 mm S-plied (spliced) thread with a thread count of 10 threads per cm. The weft is 0.35 mm S-plied (spliced) thread with a thread count of 14 threads per cm. The threads are mostly tightly twisted but also have some sections which are loosely twisted, which is typical of spliced material (fig. 5, right). The single threads used are very loosely z-twisted and about 0.15 mm in diameter.

Fig. 4: Details of the textile (Ditfurt 33) with plied thread and ESEM image of the fibres (Images: left and middle Friederike Hertel, LDA; right Uwe Schwarzer, German National Criminal Investigations Bureau, Magdeburg)

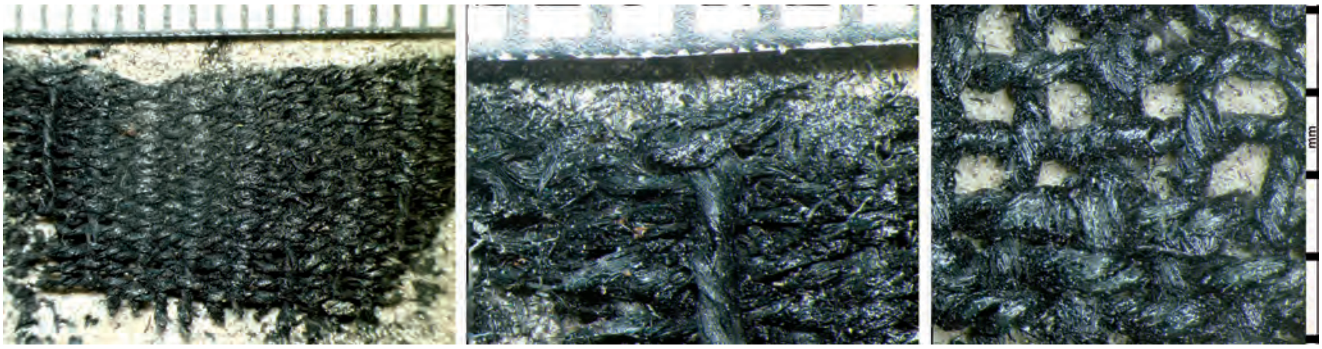

Fig. 5: Starting border on the textile from Latdorf (Bernburg) with details of the threads in an open weave (right) and dense weave (Images: Friederike Hertel, LDA)

Several textile fragments excavated in the Kreienkopp I tumulus at Ditfurt in 1933 (now catalogued as Ditfurt-33) may also belong together. The charred tabby fragments are made in an open weave and have dense starting borders with 13 threads per cm in one thread system and 30 threads per cm in the other (fig. 6, left). The plant fibre threads may well have been made by splicing like the Latdorf textiles. The cloth is likewise more or less balanced (fig. 2 and fig. 4). The warp comprises 0.3 mm S-plied (spliced) thread with a thread count of 14 threads per cm. The weft is 0.3 mm S-plied (spliced) thread with a thread count of 14-16 threads per cm. The spliced threads are usually firmly twisted, but also have some sections which are loosely twisted, which is typical of spliced material. The single threads are very loosely z-twisted and about 0.13 mm in diameter.

The newer excavations at the Kreienkopp II tumulus in 1990 at Ditfurt revealed more charred textile fragments (now catalogued as Ditfurt-90). The textiles from the second tumulus are comparable in all characteristics to the finds from 1933. Fine, open-weave tabby fragments of plant fibre were found, with further similar characteristics such as the starting border and a balanced appearance. The starting border in the new textiles has a thread count of 12 threads per cm in one system and 24 threads per cm in the other. The warp in the main weave is 0.3 mm to 0.4 mm diameter S-plied (spliced) thread, with a thread count of 12 to 14 threads per cm. The weft is 0.3 mm to 0.4 mm diameter S-plied (spliced) thread, with a thread count of 20 threads per cm. The threads are spliced with loosely z-twisted single threads of 0.2 mm diameter. Among the fragments from Kreienkopp II, fringes were also found. Some of the fringes are 5 to 6 S-plied threads twisted together, forming 1.7 mm diameter fringe threads (fig. 6, right) fringes consist of 3 S-plied threads twisted together forming in 0.9 mm diameter fringe threads.

Fig. 6: Starting border on the Ditfurt-90 textile (left) and detail of a fringe (Images: Friederike Hertel, LDA)

Fig. 7: Unterteutschenthal textile HK: 5882,1 (Schlabow 1959, Woven fragment 1). Storage in the 1950s with remarks by Schlabow (left); after conservation treatment in 2000 (Images: Friederike Hertel, LDA)

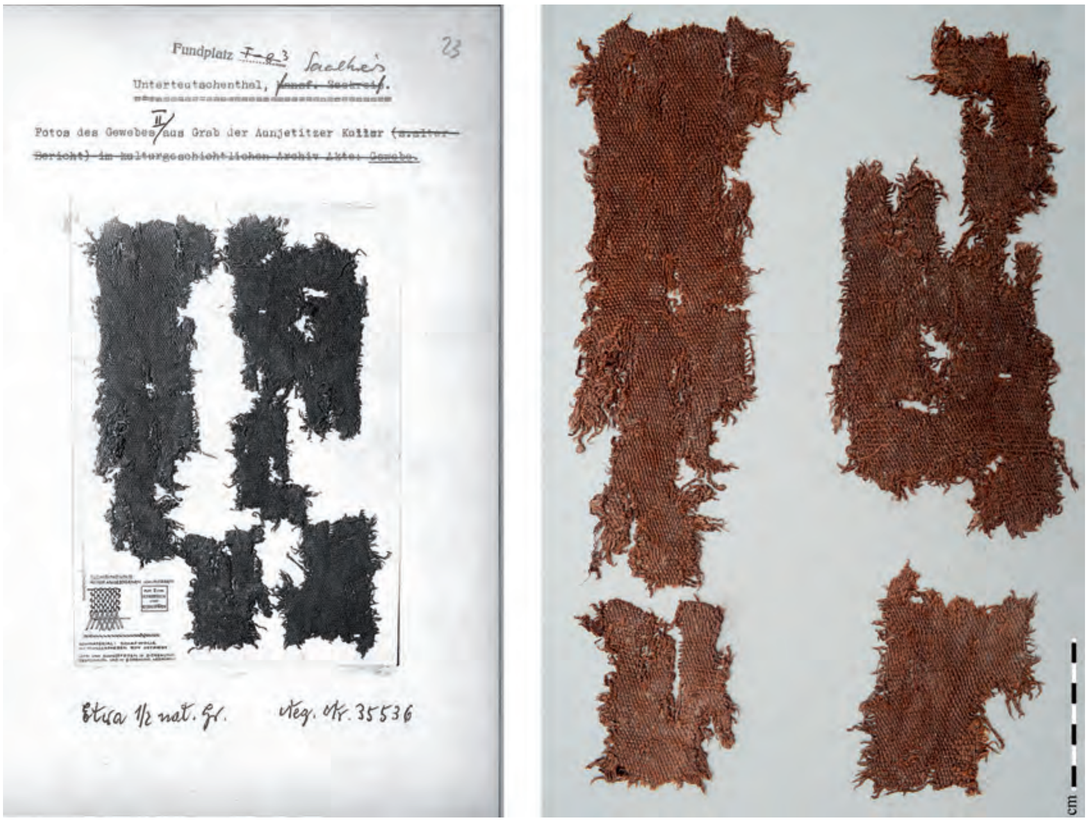

Fig. 8: Unterteutschenthal textile HK: 5882,2 (Schlabow 1959, Woven fragment 2). Storage in the 1950s with remarks by Schlabow (left); after conservation treatment in 2000 (Images: left Ortsakte LDA; right Friederike Hertel, LDA)

"Early Bronze Age" textiles from Unterteutschenthal
The textiles from Unterteutschenthal were found in tumulus II during the unsystematic excavations in 1887 by the local museum under the former director Oberst a. d. H. v. Borries (Hertel & Zich 2020). Since then, they have been stored at the Halle Museum. All textile fragments were preserved at that time by an impregnation but this was not documented. Nothing is now known about the substances used or the date of processing. However, Schlabow (1959, 119) reported: "After being conserved, the fragments [HK: 5882,2] were laid under glass on a 29 cm x 41 cm board". The reason for the reinvestigation of the textiles from Unterteutschenthal (Hertel and Zich 2020) was investment in a new storage and conservation facility for the textile finds in the year 2000 (fig. 7 and fig. 8). This revealed a white-ish substance adhering to the textile surface, which can be seen very clearly under the microscope. It is likely that this is a cellulose nitrate, which suggests *Zaponlack* or another bonding varnish (*Geiseltallack*). The use of these treatments was common in the 20th century for a long time. However, these can easily be dissolved with acetone.

The "blended weave" (Schlabow 1959, Table 17; woven fragment 1) is now under inventory number HK: 5882,1. It had been previously placed between two glass plates and almost pressed flat in the 1950s (fig. 7, left). It has now mounted on a felt fabric and covered with a glass plate without direct contact. The "ribbed tabby" (Schlabow 1959, Tables 18-19; woven fragment 2) is now under inventory number HK: 5882,1 and has been likewise remounted.

C14 analysis
The textiles were briefly identified by Walter v. Stokar (1938, 105) as Early Bronze Age because the main contents of the tumulus date to the Únětice Culture. Schlabow did not question this dating in his detailed description of the textiles from Unterteutschenthal (Schlabow 1959, 118) and this has been repeated in further publications (Bender Jørgensen 1992, 51-52; Grömer 2016, 46, 97; Möller-Wiering 2012, 126, 130). Schlabow did not realise that Middle and Late Bronze Age artefacts were also found in the same tumulus (Hertel & Zich 2020) and that the placement of the textiles among the Early Bronze Age finds was not

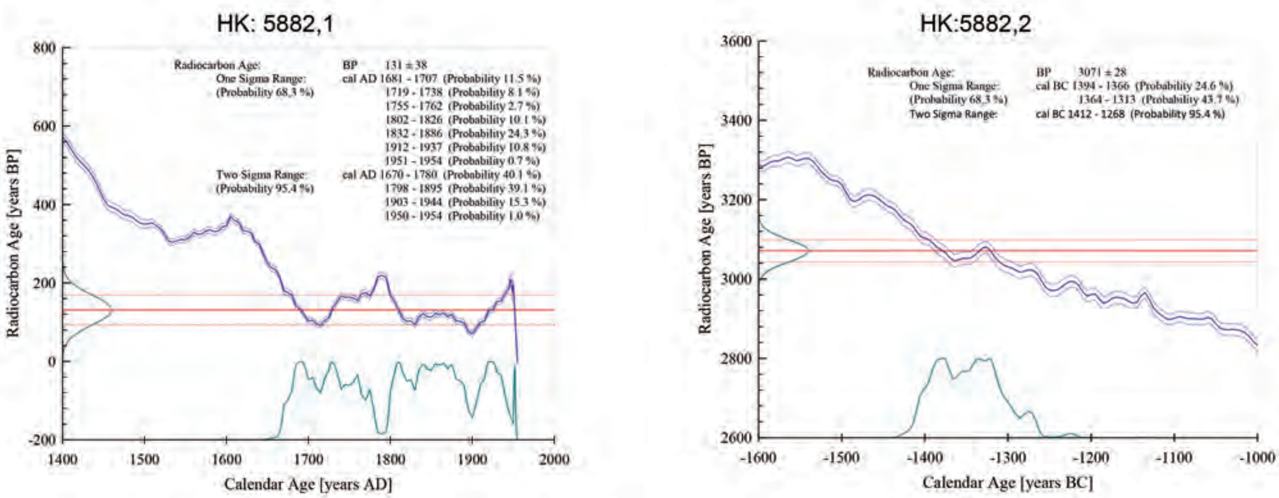

Fig. 9: Unterteutschenthal textile C14 dating carried out at Kiel University (2008)

	Laboratory	Lab Nr.	C14 age	$\delta^{13}C$(‰)	Cal1 sigma	Cal2 sigma	remark
HK:5882,1	Kiel	KIA35473	130±40 BP	-22.26 ± 0.10	cal AD 1681-1954	cal AD 1670-1954	see graph
"blended weave"	Mannheim	MAMS 19379	301±16 BP	-19.1	cal AD 1526-1643	cal AD 1521-1646	
HK:5882,2	Kiel	KIA34568	3070±30 BP	-23.14 ± 0.14	cal BC 1394-1313	cal BC 1412-1268	see graph
ribbed tabby	Mannheim	MAMS 19380	3040±19 BP	-22.5	cal BC 1375-1261	cal BC 1387-1227	

Table 1: Unterteutschenthal textile C14 dating results carried out in in Kiel (2008) and Mannheim (2014)

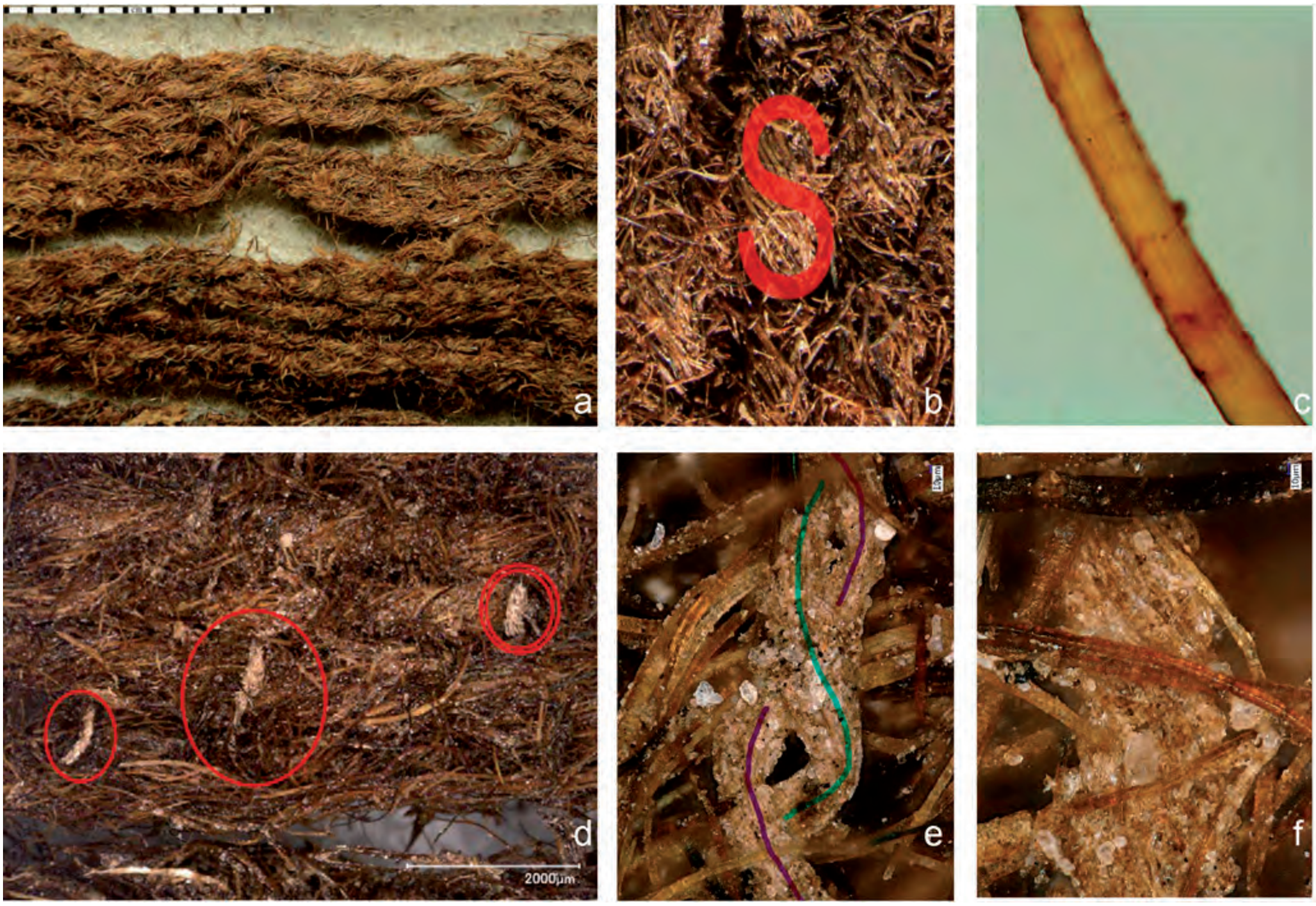

Fig. 10: Unterteutschenthal "Blended weave" textile HK: 5882,1: technical details. a) surface with disintegrated warp threads; b) twist direction weft; c) weft: light microscopy, sheep wool; d) areas with warp still intact; e) plied warp threads; f) horizontal weft wool fibres, vertical warp plant fibres (Images: Friederike Hertel, LDA)

that definite. As part of the reassessment and new conservation of the finds, the original excavation protocols were checked and this cast some doubt on the dating of the finds. It was decided that C14 dating could be used to help resolve the issue.

Samples threads from the main part of each textile were taken. The textile fragments were analysed in November 2007 to February 2008 using C14 dating at the Christian Albrechts University in Kiel, Germany (at the Leibnitz Laboratory for Dating and Isotope Analysis; fig. 9). In March 2014, additional C14 analysis of the same textiles was carried out by the Curt Engelhorn Archaeometry Centre in Mannheim, Germany to test the initial results (table 1).

Against all expectations, the "blended weave" textile (HK: 5882,1) was dated to modern times (fig. 9, left). How these fragments are related to the tumulus must now be reassessed. It is quite possible that the "blended weave" fabric is an intrusion that was introduced during the excavation in 1887. The result of the C14 dating for the "ribbed tabby" textile (HK: 5882,2) suggests it is from between 1412 and 1268 BCE. The second dating came to a similar conclusion (table 1). The two independent C14 dates (2008 and 2014) have shown that the four fragments come from the Middle Bronze Age (1550 BCE to 1250 BCE), not, as was originally suspected, from the Early Bronze Age.

Reassessment of technical data and fibre analyses

Among the finds from Unterteutschenthal, the "blended weave" textile (HK: 5882,1) (Schlabow 1959, 119, woven fragment 1), is the most iconic: "It is the first example of two different raw materials, sheep wool and plant fibres, being woven together in the Bronze Age. They are interconnected in a tabby weave" (Schlabow 1959, 119).

Despite its new dating to the modern period, the textile (fig. 10) can be described as a weft-faced tabby. The warp threads consist of plant fibres which have almost or completely disintegrated and are therefore not well preserved (fig. 10a). Only sparse fragments of thin plied threads could be documented by the use of reflected

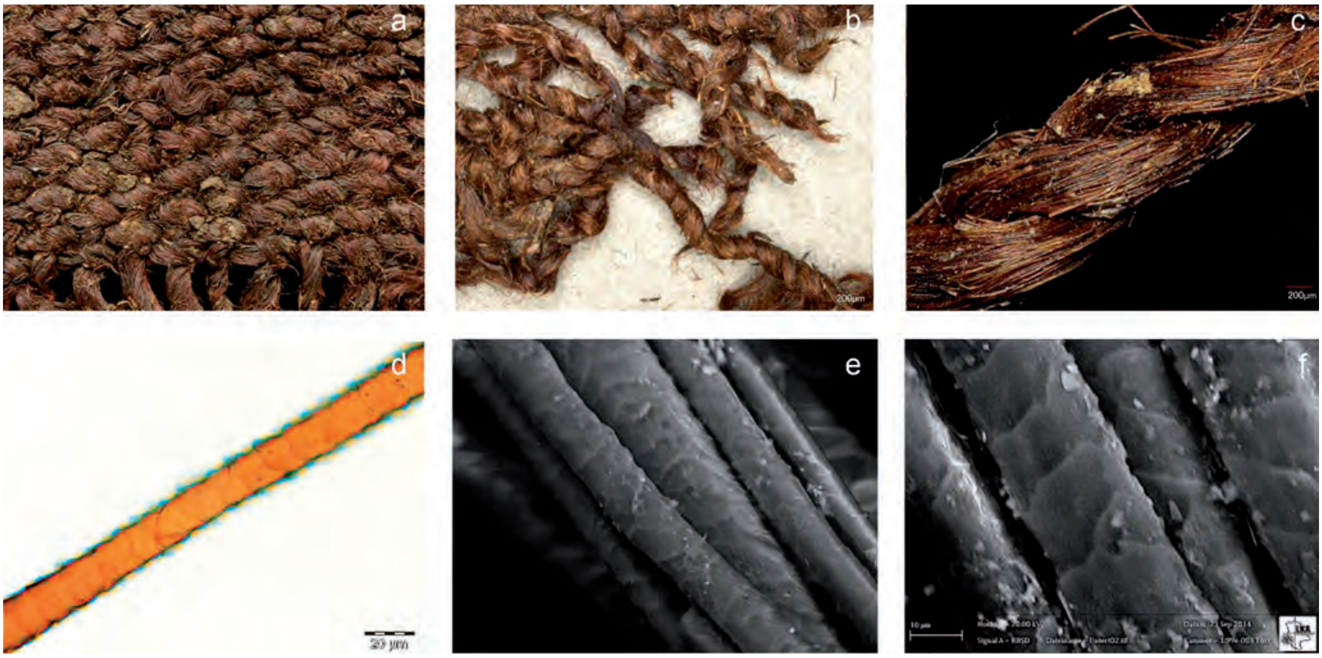

Fig. 11: Unterteutschenthal "Ribbed tabby" textile HK: 5882,2: technical details. a) ribbed structure; b) plied threads; c) more loosely plied thread; d) wool fibre, light microscopy; e-f) wool fibres, Scanning Electron Microscope (Images: a-d: Friederike Hertel, LDA, e-f: Uwe Schwarzer, German National Criminal Investigations Bureau, Magdeburg)

light microscopy at 400x and 700x with a high resolution (fig. 10d and fig. 10e). The fabric consists almost entirely of weft threads. These threads can be identified as sheep wool because the surface structure with scales is clearly visible (fig. 10c). Thread system 1 consists of 0.15 mm to 0.2 mm S-plied (?) thread, with a thread count of 4 to 5 threads per cm. Thread system 2 comprises 0.4 mm to 0.6 mm s-single thread with a thread count of 10 threads per cm. In the original analysis, there is no difference recorded between the two thread systems and the thread diameter differs from that found during the new analysis (Schlabow 1959, 119).

The "ribbed tabby" textile (HK: 5882, 2) consists of four fragments and, on sight, it differs from textile 5882,1 (fig. 11). It is also very dense in one thread system which results in a ribbed appearance. No starting borders or selvedges can be seen on the fragments, and the warp and weft directions cannot be distinguished. The fabric is dense and strong owing to the use of plied thread in both directions. Both thread systems consist of sheep wool. The characteristic scales are clearly visible under reflected light microscopy, TLM and SEM where the surfaces of the fibres have been ripped away.

Thread system 1 consists of 1.0 mm to 1.3 mm Z-plied threads with a thread count of 10 to 11 threads per cm. Thread system 2 is 1.0 mm to 1.3 mm Z-plied thread with a thread count of 5 to 6 threads per cm. The plied threads are tightly twisted except for the 0.5 mm to 0.6 mm thick s-single threads which make up the Z-plied thread which have a looser twist. For this textile, the new analysis differs only a little from the data given by Schlabow (1959, 119-120) where he does not note differences in the thread system.

Dyestuff analysis

The "ribbed tabby" (HK: 5882,2) has a reddish colour, which was described by Schlabow (1959, 119*)*. The reddish colour can be seen more on one side than on the other. It is conceivable that the brownish and slightly brighter front was more exposed to the UV light of the sun than the other side (fig. 12). Nevertheless, the reddish shade suggested dye analysis would be informative. This was carried out by Annemarie Kramell at the Institute for Organic Chemistry at Martin Luther University in Halle Wittenberg (Hertel & Zich 2020). A sample of 4 mg was taken and analysed with a diode-array detector and mass spectroscopy (HPLC-DAD and LC-MS/MS; Kramell et al. 2014). There was no firm indication of dyestuffs. The reddish colour of the textile may have been caused by chemical processes in the soil such as humus or humic acid. By the time the dye analysis was undertaken, the modern date for textile HK:5882 had already been established by C14 analysis, and it was excluded from this testing.

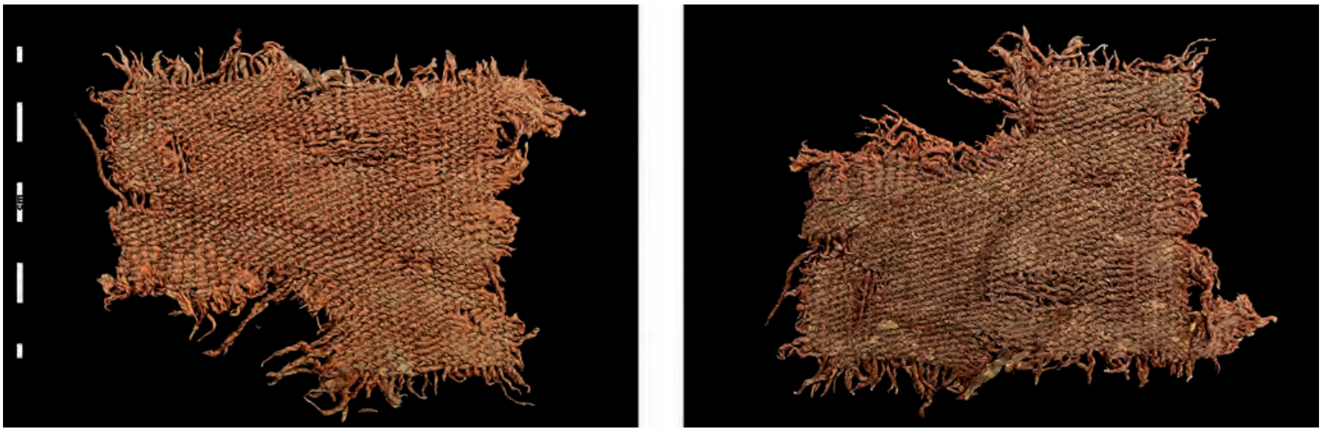

Fig. 12: Unterteutschenthal "Ribbed tabby" textile HK: 5882,2: reddish colour on face (slightly faded) and reverse (Images: Friederike Hertel, LDA)

Implications on research

Some of the earliest textile finds from central Germany are kept at Halle Museum: the Neolithic textiles from Latdorf and Ditfurt and the Bronze Age textiles from Unterteutschenthal. Thanks to their extensive and detailed publication by Schlabow (1959), the finds were referred to in several books about early textiles in Europe (Barber 1991, 176, 217; Grömer 2016, 46, 97; Möller-Wiering 2012, 126, 130) especially in relation to their dating and their technical details, which were not questioned. They have occupied an important role in our understanding of the introduction of sheep wool in Europe and other handcraft details.

The reassessment of the technical data and especially the fibre of the Latdorf and Ditfurt examples must now have an impact on our understanding of the development of textile technology in early Europe. Interpretations about how and when the use of wool reached central Germany and northwards from there may have to be reconsidered. Schlabow (1959) identified the fibres of both find complexes as sheep wool. Moreover, he specifies that it was good quality sheep wool which was carefully plucked without shearing taking only the long fibres and not the short underwool and kemp (Schlabow 1959, 115). This exciting information about Neolithic textile material was often cited. However, the renowed expert on the historical use of sheep wool, Dr Michael Ryder from Southampton, questioned the analysis of the raw material. He argued his doubts to Andrew Sherrat, who published them: "An important find in this context is the Spitzes Hoch tumulus at Latdorf near Bernburg in central Germany (DDR) … However, Dr M.L. Ryder (in litt. April 1981) informs me, that he examined this supposedly Neolithic "wool" in 1964, and is of the opinion that flax; and carbonized flax-seeds occurred in the grave (Vogt 1937, 43). It seems most likely, therefore, that this late-fourth millennium sample is linen, like contemporary Swiss textiles" (Sherrat 1983, 93). The same doubts also were expressed by Elizabeth Barber (1991, 141-142) and Lise Bender Jørgensen (1992, 51-52; Bender Jørgensen & Rast-Eicher 2015). SEM analysis has now shown these doubts to be well-founded.

More technical details concerning both find sites are of importance here: The threads have not been made of spun single threads twisted together, but with splicing – a technique and term which was not known in Schlabow's time. The use of spliced thread, twisted in the S-direction is typical for Neolithic flax textiles, especially those which were found in the lakeside settlements around the Alps (Leuzinger & Rast-Eicher 2011). In splicing (Barber 1991, 44-47; or Gleba & Harris 2018), the ends of pre-formed fibre bundles (strings or strips), stripped from the flax stalks, were spliced together, so that the ends of the ultimate fibres overlapped in bunches and at wide intervals. After this first step, two of these elements were then twisted or plied together. This fits well with our recent knowledge of how threads were produced in the Neolithic era. The techniques arise from a long tradition of working with plant material, especially tree bast (Rast-Eicher 2005).

The brief remarks of Stokar (1938) and the detailed descriptions of Schlabow (1957 and 1959) presented the important Unterteutschenthal finds for textile archaeology which stood for a long time. The dating of the textiles was regarded as firm because the associated finds were assigned to the Early Bronze Age. Consequently, this unique find from central Germany offering the earliest evidence of a blended wool fabric has become firmly integrated into scientific publications (Bender Jørgensen 1992, 52; Grömer 2016, 46; Möller-Wiering 2012).

The new, unexpected C14 dating results of the Unterteutschenthal textiles will also have an important influence on textile research. The "blended weave" fragment (HK: 5882,1) was dated to modern times (between 1640 CE and 1955 CE) and must therefore be deleted from the history books of the Bronze Age. It was firmly established as one of the earliest European examples of a textile combining wool and plant materials (Barber 1991, 176). This must now be reviewed. There is now no evidence of an early blended weave in Bronze Age Europe. There is a small band from Chania, Minoan Period (first half of the second millennium BC) made of a flax warp and animal hair in the weft with supplementary threads in nettle fibre (Spantidaki & Moulherat 2012, 189, Fig. 7.3).

The other Unterteutschenthal textile (HK: 5882,2) is now dated to the Middle Bronze Age at end of the 14th century BCE. The new dating moves this textile from the Early to the Middle Bronze which demands a reconsideration of it and comparative materials. Still, it is the oldest surviving wool fabric in Saxony-Anhalt. Ans still, it can be interpreted as a link between the textiles from Bronze Age Hallstatt and the wool textiles from the Danish bog finds.

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Textile activity and its tools
in the culturally mixed framework of Sicily between the 13th and the fifth centuries BCE

Introduction
This PhD project from the University of Liverpool (UK) which was finished in 2019, investigated the impact of cultural contacts on the indigenous traditions of making and using textile tools in Sicily between the 13th and the fifth centuries BCE. Sicily and the Aeolian islands have been crossroads for millennia and the contacts with incomers, especially Greeks, have often been perceived to have affected the indigenous material culture. The analysis of more than 1,400 textile tools from seven sites across Sicily has shed light on how textile tools and technology might have been affected by intense cultural contacts and how people were forced to renegotiate their own identity. Moreover, the study of decoration and marks on textile implements demonstrated that textile tools could be charged with new meanings and express the identity of their owners.

Background to the project
Textile activity was an important aspect of culture and economy in ancient societies (Andersson 1999; 2007; Gleba et al. 2013). The role of other economic activities in Sicily such as metallurgy and pottery, which have usually been perceived as carried out by men, has long commanded the attention of archaeologists. In contrast, textile production, for the most part undertaken by women, has not been studied to the same extent for a long time. Recently, research on textile production has gained momentum (Landenius Enegren 2015; 2017; Militello et al. 2016; Quercia & Foxhall 2014; Quercia 2018), although textual sources and archaeological evidence are limited. Written and iconographic sources provide only a little information on Archaic and Classical textiles and textile techniques (Brugnone 2008), while no evidence is attested for the Prehistoric period. Remains of actual textiles are rare, because the Sicilian climate is not favourable for the preservation of organic material (Gleba 2008, 62-63). Moreover, specific studies on the raw materials exploited, the yarn produced, and animal bone assemblages recorded and analysed are available only for a few sites (Gleba 2008, 71; Bartosiewicz 2012). Thus, the study of textile production in Sicily is mainly based on textile tools. Spindle whorls have received little interest due to the fact that they do not change dramatically in shape or decoration and are rarely found in the Archaic period. In contrast, loom weights have attracted more interest because of the large number in Archaic contexts and the variety of shapes, which have been traditionally explained in terms of cultural or presumed ethnic factors (Balco &

Fig. 1: Map of Sicily showing the sites relevant to the study (Image: Gabriella Longhitano)

Kolb 2009). Traditionally, the truncated pyramidal, conical, disc and lenticular types have been regarded as probably adoptions of Greek types, while the origin of the cube-shaped type is still debated and may derive from the indigenous or the Phoenician tradition on the basis of their predominance in the Phoenician sites of Motya (Quercia & Foxhall 2014).

Research aims

The PhD project "Textile activity and its tools: indicators of cultural identities and interaction processes in Sicily and the Aeolian islands" (Longhitano 2019) investigated the traditions of making and using textile tools in Sicily between the 13th and the fifth centuries BC. The aim of this research was primarily to test the hypothesis of using textile tools as means to explore how social and individual identities can be shaped and negotiated in response to cultural interactions with foreign people. Traditionally, pottery, architectural and social practices have been employed by post-colonial studies to investigate the impact of migrations and cultural encounters on material culture. However, drawing upon the concept of materiality (for example, Miller 2005), this study has demonstrated that textile tools are deeply and uniquely embedded in collective and individual identities because they are both tools and 'things' (Hodder 2012, 2016; Olsen 2010; Olsen et al. 2012) at the same time. Within this social and cultural entanglement, in culturally mixed frameworks, textile tools become capable of acting as agents in the construction of social and individual identity.

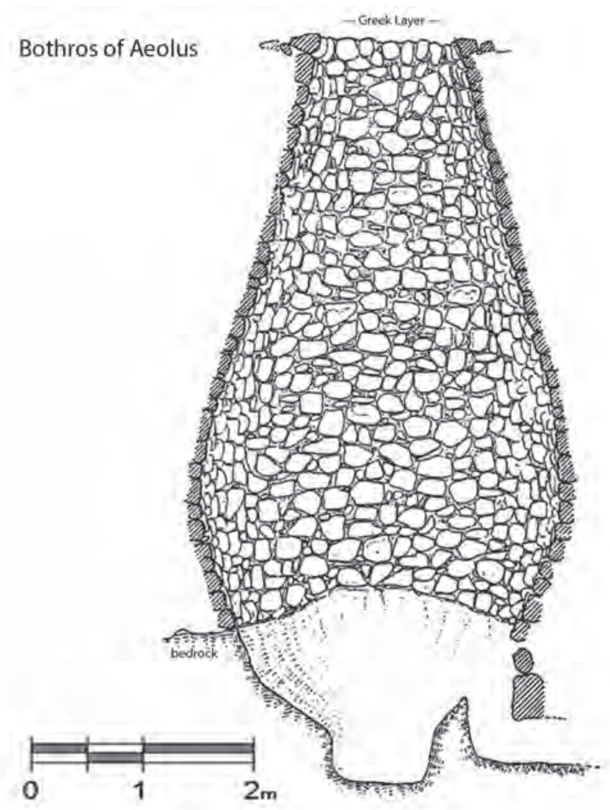

Fig. 2: The so-called Bothros of Aeolus (After Bernabò Brea et al. 1998)

Sicily and the Aeolian islands offer distinctive examples of the co-existence of different local communities which came into contact with incomers (Leighton 1999, 215-217, 219-235; Albanese Procelli 2003, 18-25, 131-136). In particular, two events have been regarded as crucial for the local communities: the movement of peoples from the Italian Peninsula during the Final Bronze-Early Iron Age and the establishment of Greek colonies from the end of the eighth century BC. Within cultural interactions, all cultures were forced to renegotiate their own identities through a process of adoption, rejection or adaptation of foreign elements. This research demonstrated that the choice of textile technology and textile tools was used as an element of self-identification and self-representation. The analysis of textile tools suggested that local communities had different approaches towards foreign textile traditions. Some local communities appear more reluctant to assimilate foreign textile tool shapes, while others seem willing to be associated with new traditions. Cultural contact mostly affects those communities where the socioeconomic relationships with the Greeks were intense. In contrast, numerous indigenous centres, mainly those of western Sicily, where the communities were also exposed to the Phoenician culture, demonstrably maintained their local weaving traditions (Longhitano 2019, 251-256).

Textile tools from settlements

For the purpose of this study, spindle whorls, loom weights and spools from seven sites across Sicily (Lipari, Metapiccola, the Cittadella Hill, Sabucina, Himera, Monte Maranfusa and Monte Polizzo) (fig. 1) were analysed. The analyses of textile tools from settlements with long lifetimes enabled the detection of changes in textile and textile tool production between the Final Bronze Age and the Archaic period (circa 1200 BC to 400 BC). One of the main changes in the Archaic period is that the number of spindle whorls fell sharply in number in the archaeological record. It is a strong possibility that ceramic spindle whorls were replaced by those of perishable materials or even by wooden spindles operated without a spindle whorl, which have resulted in a lack of archaeological evidence (Longhitano 2019, 245-246). In contrast, the

Fig. 3: A customised loom weight from Lipari bearing an oval gem impression with a flying Nike on the top (Image: Gabriella Longhitano, with the permission of Parco Archeologico delle Isole Eolie, Museo Luigi Bernabò Brea-Lipari)

analyses demonstrated that at the same time, the number of loom weights significantly increased and was accompanied by standardisation in shape and size, and a reduction in size. This result is particularly evident at the Archaic sites of the Cittadella Hill and Sabucina, where the poor quality and heavy loom weights of the Iron Age were replaced by good quality, standardised, lighter ones. This new production mode suggests that a new weaving technique (a different way of setting up looms with larger sets of lighter loom weights) was in use with an emphasis on the production of finer textiles. The turning point for this change was the arrival of Greeks, who brought and used their own textile tradition at their Sicilian settlements (for example, Himera, Lipari and Selinous) which was characterised by a focus on the production of fine textiles (Longhitano 2019, 251-256).

Textile tools and textile production in sacred contexts

This research included textile tools recovered from two sacred contexts in the Greek settlements of Lipari and Himera. These two case studies have provided the opportunity to investigate the significance of the presence of textile tools in sacred areas and explore whether weaving was practiced in connection with sacred activities. Although the interpretation of textile tools in sacred contexts is not always straightforward, their presence in such contexts adds another dimension to the relationship between these implements and their society, and enhances our understanding of the social significance of textile manufacture.

Spindle whorls, spools and especially loom weights are ubiquitous votive offerings in Italian sanctuaries and deposits from the first millennium BCE. Loom weights sometimes come in very large quantities, which might indicate the practice of weaving (Gleba 2009, 81), although the evidence for this is ambiguous.

Votive loom weights can fall into two broader categories: those manufactured for general use and then deposited and those produced specifically for ritual purpose. It is difficult to distinguish between these two categories. The analysis of use-wear marks was sometimes useful in identifying used loom weights deposited at the so-called Bothros of Aeolus in Lipari (fig. 2). This deposit, likely related to a cult area on the Acropolis and dated between the sixth and the end of the fifth centuries BCE, yielded an extremely intriguing assemblage of loom weights (Bernabò Brea et al. 1998). The analysis of functional parameters, along with that of use-wear marks and decorations pointed to a peculiar practice of dedicating complete or partial sets of either miniature or actual loom weights along with single votive offerings. Some of the loom weights deposited in the Bothros of Aeolus are likely customised as they bear impressions of local seals or finger rings (fig. 3) (Longhitano 2019, 111-112).

Deposited loom weights usually do not differ from those found in domestic contexts. However, this is not the case of the exceptionally large assemblage of loom weights recovered from the Eastern District sanctuary at Himera (fig. 4). This small sanctuary yielded a large number of loom weights in two votive deposits (rooms 39 and 25) dated between the sixth and fifth centuries BCE (Allegro et al. 1976, 473-550). These loom weights differ substantially in shape and weight from those found elsewhere at the site (fig. 5 and fig. 6). At least three recognisable groups of loom weights were identified and the analysis pointed to the production of particular kinds of dense fabric (Longhitano 2019, 187-202). This result, together

Fig. 4: Plan of the Eastern District with the urban sanctuary (After Allegro et al. 1976)

Fig. 5: Example of a discoid loom weight from Himera recovered in deposit 25 (Image: Gabriella Longhitano)

with the specific nature of this urban sanctuary strongly connected with the life of the district and the female deity worshipped there, strongly suggests that weaving activity was likely to take place at the sanctuary, perhaps under the protection of Athena Ergane (Allegro et al. 1976, 491).

The role of women in the construction of social identity through textile technology

In the study of cultural interactions in Sicily, research has been mainly devoted to pottery, metallurgy, ritual and social spaces and habits, particularly those associated with the male sphere. Recently, female roles have been investigated more closely and it has been observed that, unlike what was believed for a long time, women participated in communal ceremonies and took part in drinking and feasting in some communities along with men (Antonaccio 1997; Ferrer 2016). Although this research has represented a breakthrough in the study of Sicilian communities, scholars still recognise women as merely participants of communal ceremonies along with men, who seem to be the dominant figures. In contrast, as textile activity was mainly practiced by women, this study of textile tools showed that women played a crucial role in the choice of technology as well as in the construction and representation of social identity. They were also instrumental in the transfer of textile related knowledge and skills contributing to sharing and spreading textile tradition. This is what clearly emerges from the analysis of loom weights at the Cittadella Hill. This indigenous site shows a major change in textile production from the sixth century BCE simultaneous with the adoption of Greek urban and architectural models (Antonaccio 1997). The community develops a new way of setting up looms with a larger number of smaller and lighter loom weights, which is consistent with the Greek tradition, and points to a new and different textile production. This new textile tradition may have been adopted from a desire to produce Greek forms of dress, perhaps to be seen in a particular way or to be associated with a certain social group. It is likely that women as both producers and consumers played a crucial role in choosing new styles inspired by or imitating the Greek ones. The adoption of new technology would necessitate a period of interaction between indigenous and Greek women living at the site or at the nearby Greek settlements. Indigenous women working together with Greek women might have become familiar with new traditions and learned how to set up a loom with smaller and lighter loom weights and to produce new quality fabrics (Longhitano 2019, 147-148).

Conclusion

By applying a variety of approaches, this study of textile tools and technology has greatly enhanced our understanding of local communities in Sicily and the effects of cultural contacts on textile traditions. Local communities have shown a variety of approaches towards foreign influences confirming that mechanisms of transmission in situations of cross-cultural encounter were varied, complex and dependent on local choices and social relations.
However, the picture that emerges from this study is not complete because important questions about textile culture remain unanswered. For instance, did indigenous communities, which adopted Greek elements of textile technology, also adopt other aspects of their textile culture, such as motifs, patterns, colours, or only select specific elements? Further investigation is needed to answer this and other questions.

Fig. 6: Example of pebbles likely used as loom weights from Himera recovered in deposit 25 (Image: Gabriella Longhitano)

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Ingrid Schierer and Karina Grömer

Project TT-nhm:

A record of textile tools in the archives of the Natural History Museum Vienna

The context: the museums' archives

The Natural History Museum Vienna (NHM) was founded at the end of the 19th century to house the rich and extensive collections of the Habsburg imperial family. The building was erected on the newly constructed *Ringstraße* and the objects were presented in what was then a modern, scientific and ambitious way. The NHM was "dedicated to the realm of nature and its research". It has become the Austrian centre for the study of natural, archaeological, anthropological and ethnographical collections as the official home of objects found within the territory of the Austro-Hungarian Empire (Jovanovic-Kruspel 2015, 13-22).

Up to the 19th century, the archaeological (prehistoric) and ethnographical objects were understood to belong to the realm of *nature*, whereas artefacts of the ancient civilisations, such as those of Egypt, Greece and the Roman Empire, were regarded as works of *art*.

The collections of the Department of Prehistory at NHM hold more than one million objects, the origins of which cover an enormous timespan and a wide geographical range. Most of these objects were found within the former territory of the Habsburg Empire. In its widest geographical extension, it covered a territory from what are now known as the Czech Republic, Slovakia and the southern part of Poland in Central Europe, continued to the southern Balkan regions of Bosnia/Herzegovina and Bulgaria, and stretched from Tyrol and northern Italy in the west to Ukraine and Rumania in the east.

A large number of the objects stored at the Department of Prehistory came from the imperial Habsburg collections. The NHM also carried out its own excavations. Over the years, objects which have become very famous (Grömer & Kern 2018) have been found; for example, the female figurine *Venus von Willendorf* (29,500 years old), as well as the organic and non-organic artefacts found in Hallstatt, the UNESCO World Heritage Site in Upper Austria. Some objects, found in places which did not belong to the Habsburg Empire, were given to the NHM by scientists from other countries.

The artefacts: textile remains, textile tools

Among the artefacts stored in the archives, there is also a great number of textiles which were preserved in the Hallstatt salt mines (Grömer et al. 2013), mineralised (Bender Jørgensen 2005; Grömer 2014), corroded onto metal objects or as imprints in pottery. In addition, the archives hold more than 4,000 textile tools (fig. 2 and fig. 3) which were found in various circumstances: for example, in graves, settlements, and also in hoards in several different parts of Europe

Fig. 1: Logo (Image: Michaela Almstädter)

Fig. 2: Textile tools from Bad Fischau, 600 BCE, stored at NHM (Image: Alice Schumacher © NHMW)

and across prehistoric eras. The tools used to make woven textiles cover a timespan from the earliest farming societies in the Danube area (5600 BCE, the beginning of Linear Pottery) to the end of the Early Medieval Period (900 CE). Not only spindle whorls and loom weights are kept at the museum but also sewing needles, weaving swords and flax hackles. Some other artefacts may have been involved in textile production but, until now, how they were used has not been confirmed.

The TT-nhm project: key sources and initial work

A study of textile tools has become a scientific requirement in Austria in recent decades. While needles and spindle whorls were given great attention by archaeologists, loom weights are still usually found in publications under the heading "Other Finds". This marginal position in conventional archaeological research in Austria also led to only sparse discussion about the function of the loom weights, in regard to their geographical distribution and temporal classification. The TT-nhm project aims to overcome this and make data from spindle whorls, loom weights and other textile tools available for future research.

The work to be carried out in the first phase of the project is basic registration: more than 4,000 textile tools stored at the NHM archives are to be described (fig. 4 and fig. 5). This will include measuring the weight, diameter, height, etc., describing the surface, and the patterns resulting from use (if apparent). Production features and conservation status will also be recorded. Documentation is done with photographs and drawings (in special cases).

In contrast to other ways of studying archaeological material, such as writing a scientific monograph on a

Fig. 3: Loom weight prepared for documentation from Katharein (now Kateřinky, Opava, Czech Republic) (Image: Ingrid Schierer)

Fig. 4: Iron Age spindle whorl from Leopoldau prepared for exhibition (the wood and wool are replicas) and the original documentation of the site (Image: Karina Grömer © NHMW)

distinct site or a special topic, this project work will collect the features of objects and make them available to scientists as a digital database.

The project: protocols and essential skills

The textile tools (mainly spindle whorls and loom weights) stored in the NHM were found in old excavations and recorded in handwritten archive material. This will also be studied to understand the find contexts of the textile tools. This valuable archive information will be deciphered and transcribed from labels, letters, diaries, inventories and excavation reports to understand where the tools come from, where exactly and in what position they were found in graves and settlements etc. plus other relevant details (fig. 4). This is part of the citizen science activities (NHM_Fundakten_2019) to be carried out by historians and other people with the ability to decipher the German *Kurrent* script used until the beginning of the 20th century, which differs considerably from the modern German script used now.

The project structure: co-operation partners and volunteers

The TT-nhm project was initiated to allow scientific access to all the textile tools stored in the archives of the NHM. It began in 2018 and is planned to last to at least 2022 (Schierer 2019). It is based on the standardised recording proposed by the Centre for Textile Research in Copenhagen (Denmark) known as the Tools Database CTR (Andersson Strand 2012;

Fig. 5: Storage of artefacts not on display at NHM and work with textile tools (Image: Karina Grömer)

Andersson Strand & Nosch 2015; Mårtensson et al. 2009; Olofsson et al. 2015).

The project in Vienna is arranged as a student trainee programme and as a citizen science activity. The NHM has integrated citizen science activities into all of its departments. They offer opportunities for those who wish to use their non-academic skills in scientific activities (NHM_Citizen_Science_2019). It puts special emphasis on research and communication with the aim of sharing relevant scientific insights with the public (Ott & Schmid 2019, 38-40).

Co-operation with the University of Vienna is also part of the project. The curriculum for the master studies at the Institute for Prehistory includes training in analytical techniques for archaeological artefacts made from a variety of materials. In the context of their studies, the students can participate in the project.

Another collaboration is with the open-air museum MAMUZ in Asparn/Zaya in Lower Austria (www.mamuz.at). Answers to some of the questions arising from the project can only be found in experimental archaeology. Some of these experiments for observing functional aspects of the tools will take place at this site. Annual lectures for students to learn textile techniques, such as spinning and weaving, are also part of the curriculum.

Student/researcher exchange networks, such as the EU Erasmus programme which offer the possibility to undertake studies abroad. These students and researchers will share valuable expertise on these subjects. One Erasmus exchange student from *Freie Universität Berlin* (Lau, in preparation) studied finds belonging to the East Hallstatt Culture. Not only did she record tools, she also analysed textiles attached to metal objects from grave finds in Slovenia, studied dress accessories with their placement in graves, and engravings found on bronze vessels (*situlae)* from the same sites. This comprehensive approach to the textile culture and textile production was possible through access to the wide variety of objects stored and recorded in the NHM archives and inventories.

Outlook: open access to datasets for further studies and experiments

Ever since the spread of the earliest farming cultures, textile production has been an important aspect of the history of humankind. The influence textile production has had on economic, social and technical spheres in the Neolithic period still exists today.

Loom weights are, at first glance, more or less of the same shape (perforated discs and perforated truncated cones) but differ in detail – and there are still finer differences to be found. The form of the holes requires special attention because it will probably permit statements on the details of the weaving technique and/or the construction of the loom to be made.

It is planned that all data will be made available through open access at the end of the project. It will be accessible on the "Textile Research" page on the website of the Department of Prehistory (NHM _ Textilgeraete_2019). One of the outcomes will be a mapping exercise using the characteristics of textile tools in various parts of Europe. This "Big Data" approach to research leads to helpful overviews of chronological and regional trends in textile tools.

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A new international project: The fabric of my life

The Fabric of My Life (known as FABRIC), is a collaborative project between cultural institutions in Denmark, Greece and Denmark with the aims of innovating and testing new methods for exploring migration history in the cultural sector, empowering refugee women, and training cultural workers and design students. It was enabled by support from the Creative Europe Programme of the European Union, and will run from 2018 to 2022.

FABRIC fosters new digital and cultural productions co-created with refugee women. Clothing is an immediate, tactile, tangible and visual means of communication among Europeans and with the new citizens. Yet female clothing has become a contested field in this context. Scholars have used various paths to explore "modest fashion" and how it is practiced in new localities when forging new lives (Klepp & Bjerck 2014; Klepp et al. 2014).

In FABRIC, clothing is acknowledged as an individual means of communicating identity, history and a better future. European and refugee women are invited to co-create and contribute to exhibitions in digital, pop-up, and conventional formats, and use clothing to narrate their life stories: Who taught me to knit? What did my grandparents wear? Who made my wedding gown? What is appropriate dress for me? The FABRIC team also co-creates podcasts of these narratives in several languages. There are plans for exhibitions of clothing and digital recreations of wardrobes lost during conflict. These cultural products are powerful dialogues reflecting and restoring memories of lost histories, both within Europe and beyond. They give a voice to a wide public in Europe and they offer culture, reflection and entertainment in various European languages, as well as in the languages of the new European citizens: Turkish, Kurdish, Arabic, Farsi, Tigrinya and more. FABRIC wishes to promote the view that refugees not only need food, clothing and shelter but also access to art, media and culture.

Flight and immigration are not new phenomena but age-old formative experiences in Europe. FABRIC therefore links to other historical movements of people in the 20th century in Europe through memories and cultural heritage in oral narratives of female migrants. Forced migration often requires a departure with only clothes and some jewellery and other valuables in a suitcase. The latter are usually lost or sold in transit, leaving just the clothes as objects of memory. Greek families possess clothing that was brought from Asia Minor in 1922; German families have clothing from their flight after World War II and from each side of the Iron Curtain. Likewise, today's refugees from north Africa and the Middle East travel with modern clothing items. And, in their new lives, these clothing items gain new value as tokens of memory embedded with new meaning symbolising personal histories. Anthropologist Mark Vacher has suggested that these objects from the home culture are endowed with "disporean longing" (2007). They contain special meaning, are carefully preserved, and not likely to be donated to a museum or discarded. FABRIC will use voice recordings and photographic documentation to include these objects in sensitive public storytelling with descriptions and narratives of their meaning by their owners. The narratives are recorded in the speakers' mother tongues. Fashion and clothing scholars have previously demonstrated how wardrobe biographies of refugee and migrant women can become a key to understanding journeys of immigration in which dress objects connect past, present and future, and express memories, dreams and aspirations for individual people (Bang 2013).

Since the European refugee crisis began in 2015, artists have used refugees' clothing as a way of starting debates and reflections in galleries and art museums. Chinese artist Ai Weiwei curated the art project Laundromat as well as an installation of clothes left behind by Syrian refugees in a camp in northern Greece in a New York gallery. The National Museum of Contemporary Art in Athens featured a special exhibition FACE Forward… into my home. Portraits and Stories of Refugees from November 2017 to January 2018, co-funded by the Greek Ministry of Culture and Sports, the United Nations Refugee Agency and the European Union's Civil Protection and Humanitarian Aid.

At the ICOM Costume Committee Annual Meeting 2017, Greek social anthropologist Elia Petridou discussed the public display of a woman refugee's black dress collected on the shore of Lesbos in Athens. The dress was displayed in the Museum of the History of Greek Costume in Athens with garments from the 1922 refugee crisis. This comparative display demonstrates the combination of two bodies of evidence for refugees' experiences, which FABRIC very much want to emulate. Petridou raised crucial questions about the intimate embodied experience of displacement, the biopolitics of provision of humanitarian aid, environmental issues, and the politics of representing "refugeeness" in museum displays and exhibitions.

FABRIC partners include cultural institutions in three European countries: in Denmark, the Centre for Textile Research, the Design School Kolding and the National Museum of Denmark; in Germany, Deutsches Textilmuseum, Krefeld and the Akademie für Mode und Design, Düsseldorf; in Greece, ARTEX. Most of the partners have previously been involved in initiatives at the crossroads between migration, integration, gender and dress. In the THREAD project (2017-2019), Danish private and public partners used textile craft and culture as a catalyst for encounters between refugee women, local craft organisations, and potential employers (Malcolm-Davies & Nosch 2018).

In FABRIC, textile art and textile artists are given space and opportunities to visualise the bonds between women, migration and textile cultural heritage. Two talented female textile artists, Solvejg Berg Søndergård from Denmark and Rezvan Farsijani from Iran/France, work with refugee women as collaborators in art workshops. This co-creation is accompanied by artist's talks, open virtual/digital workshops and pop-up exhibitions.

FABRIC is still collecting voice recordings of personal clothing stories and all contributions are welcome. The podcast platform is constructed by the social enterprise and coding school Hack Your Future (HYF), whose volunteers train refugees in digital media and programming skills. The FABRIC podcast platform has become a training project for the portfolios of refugees attending HYF's courses. If you are interested in sending us a podcast about the fabric of your life, or if you wish to volunteer as a podcast interviewer, please contact us: ctr@hum.ku.dk

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Ulrikka Mokdad

The Margrethe Hald archive: Digitisation and communication

In 2006, the Centre for Textile Research (CTR) at the University of Copenhagen in Denmark acquired the archive of the renowned Danish textile scholar, Margrethe Hald. Thanks to a grant from Agnes Geijer's Foundation, the Margrethe Hald Archive was digitalised from 1 January to 30 June 2019, and her work made accessible to everyone who is interested in it. A thorough bibliography has been compiled and published together with articles, books, slides and photos at the CTR homepage.

Margrethe Hald (1897-1982) was a Danish weaver and textile scholar who worked as a curator at the National Museum of Denmark in Copenhagen between 1947 and 1967. As a young girl, Margrethe Hald had learned weaving during her stays at Vrigsted Højskole and Askov Højskole in Jutland. During her studies at Tegne- og Kunstindustriskolen for Kvinder, Margrethe Hald was encouraged by her teacher, Elna Mygdal, a researcher of popular embroidery, to study the textiles at the National Museum of Denmark. Her investigations and analyses formed the basis of her work *Tablet Weaving in Danish Antiquities* (1930). Margrethe Hald published numerous books on textile techniques besides studying textiles and garments all over the world.

Margrethe Hald received her doctorate in 1950 for her thesis *Olddanske Tekstiler*, a body of work that was groundbreaking for its technical analyses and which is still considered to be fundamental in international textile research. *Olddanske Tekstiler* was translated into English in 1980 and published under the title *Ancient Danish Textiles from Bogs and Burials.* Margrethe Hald had particular skills in communicating cultural history to a wide audience and she was a diligent writer, even in the non-academic world.

Margrethe Hald is, first and foremost, renowned for her work on textiles in Antiquity, but thanks to her extraordinary technical understanding of weaving and her rich cultural and historic knowledge, she also managed to put the historic textiles of the nordic countries and the contemporary textiles of the Middle East and South America into context.

From her many study trips in Denmark and around the world, for example, to Syria and Peru, Margrethe Hald brought back notes, photos and objects for further examination at the National Museum of Denmark, some of which are now in the archive at CTR.

Since the opening of CTR in 2005, researchers have continued to build on Margrethe Hald's work by means of contemporary methodology, and her doctoral thesis *Olddanske Tekstiler* continues to represent a cornerstone for the research carried out here.

Everyone at CTR and in the broader textile research community is now thankful to Agnes Geijer's Foundation which has given CTR the possibility of making Margrethe Hald's groundbreaking work accessible to all those who are interested in it. The entire bibliography is now online, and with links to most of the articles - see: https://ctr.hum.ku.dk/…/the-margrethe-hald-archive-digital…/.

Internet source:

Dansk Kvindebiografisk Leksikon, http://www.kvinfo.dk/side/597/bio/44/origin/170/ (accessed: 31.10.2019)

Drawing by Farzana Khosrawi, CTR

Christina Rinaldo 1944-2019

Christina Rinaldo died on 21 January 2019, aged 74 years. Christina studied Textile Design from 1969 to 1971 at Konstfack, Stockholm in Sweden, and from 1971 to 1972 at Konstindustriskolan in Göteborg. In 1976, she succeeded Ulla Cyrus-Zetterström as head of the handweaving school, Väfskolan, attached to Textilinstituttet in Borås, Sweden. Christina was a firebrand who saw possibilities and acted upon them. Thanks to Christina's hard work, handweaving was accepted as a school in the University College Borås, and it became possible to take a bachelor's degree in Textile Science and Handloom Weaving. Plans were also made to add a master degree to the school but, unfortunately, this did not succeed, and, after Christina's retirement in 2008, handweaving was abandoned as a separate programme and became part of Textile Design.

I first met Christina in 1993, shortly after I had achieved a postdoctoral position at Göteborg University. She was then working on a reconstruction of the Golden Gown of Margrethe I (1353-1412), Queen of Norway, Denmark and Sweden. The result was intended for an exhibition on the History of Sweden at the State Historical Museum in Stockholm. I saw an article in the local newspaper on the project and went to Borås to have a look. At that time, the main room at Väfskolan was filled with looms, including drawlooms and jaquard looms, but, as it was Sunday, all the looms but one were silent. Christina and a colleague were there weaving the golden cloth. As their deadline was short, they hardly had time for a break but still Christina took her time to tell me about the project, and how they had spent all the money on real gold thread from a specialist workshop in Lyon.

Christina Rinaldo (Image: Annie Andréasson)

The following year, I arranged a seminar on archaeological textiles at Göteborg University, which Christina also attended. One of the speakers, Gillian Vogelsang-Eastwood, gave a talk on Tutankhamun's wardrobe, and Christina was instantly fascinated. She invited Gillian to Borås and turned the recreation of Tutankhamun's garments into the next term's student project. This collaboration developed further, resulting in the exhibition *Tutankhamun's Wardrobe* which put Universty College Borås on the map nationally and internationally. It was mentioned in the *New York Times*, something that the vice-chancellor often cited as his institution's main claim to fame!

Christina co-organised NESAT VI with me in 1996, on her home ground at University College Borås, and made sure it became a memorable occasion for the participants as well as for her own students.

Christina was first and foremost a hands-on person. She made the construction of exact replicas of archaeological or historical textiles an important part of Väfskolan's curriculum. Matching yarns and weaving techniques of the past was a challenge and taught her students to master their craft. She was also an excellent speaker, much sought after by craft associations all over Sweden. She was awarded a Gold Medal by the King of Sweden, and the Ulrika Eleonora Medal by the Swedish Craft Association. In 1997, she received an award from University College Borås for creativity in teaching. Perhaps Christina's most lasting lecagy is her students. Several of them became seriously interested in archaeological textiles. Among them can be counted Martin Ciszuk, Sunniva Halvorsen, Viktoria Holmqvist, Lena Hammarlund, Amica Sundström and Kathrine Vestergaard, who each made important contributions to the field of textile research.

Lise Bender Jørgensen

Current research in textile archaeology along the Nile

21-22 January 2019, Copenhagen, Denmark

The TAES Network (Textile Archaeology in Egypt and Sudan) was launched in 2018 and this new TAES initiative, the *Current Research in Textile Archaeology along the Nile* conference, was inspired by the growing international research community of scholars working with textile cultures along the Nile. It took place on 21 January 2019 at the University of Copenhagen, and was followed on 22 January by a presentation by Egyptologist and curator of the Egyptian textiles in the National Museum of Denmark, Anne Haslund, and by a visit to the Egyptian collection in the Ny Carlsberg Glyptotek. The event was hosted by Egyptologist Anne Drewsen, art historian and handweaver Ulrikka Mokdad, and archaeologist Elsa Yvanez at the Center for Textile Research (CTR). The conference day was particularly intended to showcase new research projects currently undertaken in the field of textile archaeology along the Nile valley, many of which are led by young researchers. The papers were divided into two sessions: *Methods and Techniques. Renewed Interest in Ancient Textiles from Egypt and Sudan and Interdisciplinary Approaches* and *From the Field: Current Research on Ancient Textiles*.

Valentina Turina and Mathilde Borla (Turin Museo Egizio, Soprintendenza Archeologia Città Metropolitana di Torino) gave a paper on *The Study of Textiles of the Museo Egizio: A Work in Progress*, which presented their ongoing multidisciplinary work on the museum's collection of shrouds, nets, tunics and bedcovers. This includes, in particular, entire Old Kingdom tunics, knotted pile furnishing textiles, and the extremely rich New Kingdom tomb of Kha and Merit, with approximately 200 m of cloth. The collection of Old Kingdom pleated dresses has also received special focus, in particular on the techniques of pleating and the identification of fixing agents. Specific studies identifying dyes on Coptic textiles and red dyes on Pharaonic fabrics have been published in recent years. Currently, the team is gathering all the new information in a database, including the technical information relevant to textile techniques and to conservation.

Eszter Mátyás (Hungarian National Museum) presented a precious collection of 182 tapestry-woven Coptic textiles and her assessment of the outstanding conservation issues stemming from inadequate storage in the past. Her paper was called *Reappraisal of the Late Antique Textile Collection from the Department of Antiquity, Hungarian Museum of Fine Arts.*

Ulrikka Mokdad (CTR) reported on progress on the project *Spiral Textiles. Ancient Techniques – Modern hands.* A papyrus fragment, dated to the third and fourth centuries CE and kept in the Kelsey Museum of Archaeology at Michigan University (United States), was the origin of the project. It contains no text but is covered with painted spiral patterns. In 2016, textile scholars Ines Bogensberger and Julia Galliker invited textile craftspeople worldwide to experiment with this pattern (see ATR 58/2016, 102-104). The intention was that skilled craftspeople would recreate the spiral pattern and test whether it could have been made for the purpose of textile design. The scholarly papyrological studies and relevant bibliography were shared through a website and Facebook page. At the deadline in May 2017, more than 50 textile artists and craftspeople from 27 countries had contributed to the project, using a wide range of textile techniques. The works have subsequently been exhibited in several countries.

Cary Karp (Uppsala University) gave a paper entitled *The Museological Value of Misattribution,* which explored the gaps and pitfalls between museological attributions, terminology, technical features translated from one language to another, and charts and technical drawings. Examples included 'nålebinding', 'slipstitch crochet', and 'vansöm'. The methodological challenges presented are all the greater because the bulk of non-woven material is without secure date and not usually undergoing radiocarbon C14 analysis. Anne Marie Decker (independent researcher) continued this thread in her exploration, *Charting the Nålbinding of the Nile,* in an attempt to chart nålbinding geographically and over time. She observed variants in the Roman-Coptic corpus in 2/3 cross-knit looping/simple nålbinding with many two-toe socks for children and adults, while compound nålbinding is mainly attested in adult single-toe socks. She also demonstrated her investigative work in tracing relevant items from Egypt now in collections worldwide. She raised awareness that the so-called "Tarim stitch" is named after Tarim Basin hats, which are not actually made in Tarim stitch or a cross-knit technique.

Elsa Yvanez (CTR) presented her research project, *The TexMeroe Project: Towards an Integrative Archaeology of Textile Production,* and argued for a more integrated approach to textile production along the Nile, in terms of methods, sources and theories (see ATR 60, 2018, 105-109). Thanks to a network of international partners, Yvanez investigates ancient cotton and thread production, based on archaeobotanical and ancient tools discoveries. The large assemblages of spindle whorls, similar in size and weights, suggest a controlled and standardised Meroitic cotton thread production. The challenge in understanding textile production is that only little is known about the Meroitic societal and economic organisation. Her preliminary results therefore must go hand-in-hand with the progress of the archaeological survey and excavations in the area.

Alistair Dickey (University of Liverpool) presented *Textiles in the Elite Cemetery at Hierakonpolis: Fresh Investigations in 2018,* his on-going doctoral research project on textiles in Predynastic Egypt. Despite the many obstacles and a highly fragile and difficult material, some preliminary observations could be retrieved and shared. The characteristics of these early textiles include plain tabby weave, with a visible higher quality in elite burials (more homogeneous, thin yarns and a higher thread count). Some yarns also seem to have been spliced. Continuing the investigation of Hierakonpolis textiles, Anne Drewsen (CTR) presented an extraordinary find from Hierakonpolis in *The Elephant's Shroud*. The elephant was buried wrapped in linen and with luxury grave goods circa 3500 BCE. The size of the shroud was estimated to be 20 metres square. Anne used spinning and weaving tests to calculate the production time to a total of about six months' full-time work for one person (see this ATR, 3-13).

Tatiana Verdon (SUNY, Fashion Institute of Technology) presented her *Scientific Analyses and Technical Study of Three Ancient Egyptian Textiles from the Tomb of Hatnofer and Ramose, Western Thebes, New Kingdom, Dynasty 18, 1550-1295 BCE*. The reported size and quality is considerable: 599 cm x 178 cm, in a balanced tabby, with circa 80 threads per cm. The new radiocarbon C14 analysis gives a date of 1425 BCE. It is a very good example of the information that can be gained by returning to the well-preserved New Kingdom funerary textiles curated in many museums today but still under-studied.

Katarzyna Kasprzycka (University of Warsaw) introduced the textile and terminological aspects of textiles in ancient Egypt in *Tracing Clothes in the Ancient Temples and Documents*. Textiles came to the temples as taxes or salary for the priesthood, as well as offerings to the gods. Kasprzycka examined in detail a text from Ramses III's reign, which mentions various linens of royal quality, as well as tapestry weave.

Ziff Jonker (University of Copenhagen) chose a conceptual approach to wrapping and unwrapping bodies in a funerary context: how it was practiced, what was its economic value and textile prices, how it appears in the archaeological record, and the meanings of textiles in sensory and mythological aspects of the cult. She highlighted the close relationship between textiles and bodies in the Egyptian corpus of data in *The Practice of Wrapping in Tutankhamun's Burial in a Comparative Perspective.* The funerary wrapping of the dead could demand up to 375 metres square of textiles and could take 15 days to achieve.

Sarah Hitchens (University of Liverpool) presented the advances made in her doctoral research about textile production in Qasr Ibrim, a site at the border between Egypt and Sudan densely occupied from the Napatan to the Ottoman periods (eighth century BCE to 1811 CE). Her paper *Qasr Ibrim: Its Tools and Textiles* gave an overview of the documentation across this long period with many textile implements and very well preserved textiles curated at the British Museum and Bolton Museum. She discussed ways to relate these two types of data to better understand textile manufacture as a whole.

Magdalena Wozniak (IKSIO-PAN, Polish Academy of Science), in *Nubian Textiles project – an investigation of textiles and textile production of medieval Sudan,* chose several case studies from her Marie Skłodowska-Curie fellowship research, spanning tools, textiles, archaeological discoveries, and iconography. She proposed a new frame of reference to address the role and meaning of textiles and clothing in the kingdom of Makuria.

Thanks to a collaboration with the University of Wales Trinity Saint David and Magdalena Öhrman, all conference presentations were streamed online through the Panopto© platform and are still accessible (see link below).

The TAES conference took place under the auspices of CTR, where several scholars, who are currently developing research projects on Egyptian and Sudanese textiles, have received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie actions: Elsa Yvanez (743420-TexMeroe), Anne Kwaspen (844179-TUNICS), and Maria Mossakowska-Gaubert (701479-MONTEX). Conference speaker

Magdalena Wozniak is also funded from the European Union's Horizon 2020 research and innovation programme (COFUND-665778). Maria Mossakowska-Gaubert also hosted an interdisciplinary workshop in November 2017, including archaeology, terminology and ancient history (see *ATR* 59/2017, 99-100), which is cublished in 2020 by Zea Press: M. Mossakowska-Gaubert (ed) *Egyptian Textiles and their Production: "Word" and "Object" (Hellenistic, Roman and Byzantine Periods).*

The TAES network will continue to develop events and content. If you wish to receive its newsletter, please register at taes@hum.ku.dk.

Internet sources

Conference livestream: https://uwtsd.hosted.panopto.com/Panopto/Pages/Sessions/List.aspx#folderQuery=%22taes%22&folderID=%22913d3640-037f-47c5-b341-a9d90123ac81%22

https://spiraltextile.com/

http://centrumnubia.org/en/projects/nubian-textiles/#

TAES: https://ctr.hum.ku.dk/people/ctr-networks/textile-archaeology-in-egypt-and-sudan/

By Marie-Louise Nosch

FIBRES in early textiles from prehistory to 1600 CE

6-8 June 2019, Glasgow, UK

The 16th biennial Early Textiles Study Group (ETSG) conference, *FIBRES in Early Textiles from Prehistory to 1600* CE was held at the University of Glasgow and was attended by academics, museum professionals, and independent researchers representing more than 15 countries. Two days of presentations on a wide variety of topics, both in subject matter and geographical scope, were followed by a tour of the Centre for Textile Conservation and an optional day trip to fibre-related sites across central Scotland.

The first day focused on fibre identification and procurement, whereas the second was refreshingly filled with research on fibres and textiles from non-European sources. The conference, opened by Susanna Harris, was dedicated to the memory of Karen Finch. Initial presentations by Karen Finch's daughter, Katrina Finch, and Philip Sykas, highlighted Karen's work on metal threads and the development of an open-access, online database (see http://karenfinchtextiles.com) that will make Karen Finch's invaluable archive and research available to all.

The morning sessions, chaired by Margarita Gleba, focused on fibre identification and identification techniques, first in plant and then animal-based sources. A common theme throughout the conference was the importance of accurate fibre identification and the implications this has for contextualisation of textile remains both newly-discovered and in collections. This was highlighted in a Skype presentation by Penelope Walton Rogers, who gave an example of finding llama fibre in the analysis of the Rønbjerg textile thereby altering the provenance and dating from Iron Age to a post-14th century item. The session's presenters addressed the problem of identification with modern, technology-based solutions, including the in-development FIBRANET database, presented by Christina Margariti. This database will provide comparisons between modern, artificially degraded fibres and archaeological samples in an attempt to demonstrate the changes to morphology that can occur during the process of degradation. Difficulties distinguishing between plant and especially bast fibres was another common theme across the conference, and the following two papers addressed this issue through the application of computer imaging technology. Hana Lukešová discussed her use of microtomography to establish visual characteristics that can be used to identify fibre from the hop plant. This can bear striking similarities to cotton and is often only associated with brewing in the archaeological record. Jenni Suomela presented her work using micro-CT images in the study of the textiles from Ravattula, Ristimäki in Finland, where she has been seeking to identify the species of plants

Conference attendees outside the University of Glasgow (Image: Sarah Hudson)

used in their production, with especial emphasis on locally available materials.

The theme of scientific advances continued in the following animal-fibre session. In consecutive papers, Chinese researchers Zheng Hailing and Bing Wang talked about the recent development and practical applications of enzyme-linked immunosorbent assay to identify silk protein fibres. This technology has been further refined into a small test-strip that can be used on site to determine silk species, even in heavily degraded, mineralised or carbonised textiles. There was, predictably, much excitement in the resulting discussion.

Discussion continued into the lunch break, during which time attendees were able to review posters which covered a broad range of fibre topics whilst also enjoying drop-spindle flax-spinning demonstrations by handweaver and independent researcher, Ruth Gilbert. Representatives Lynn Abrams and Christelle Le Riguer from the University of Glasgow were also on hand to discuss the unique Cochno Wool yarn project, in which small batches of professionally spun yarn is produced from the sheep flock owned by the institution's veterinary school.

The emphasis of the afternoon sessions turned toward procurement and processing methods. The wool procurement session, chaired by Hero Granger-Taylor, began with a discussion of the practice of plucking wool (rooing) in Shetland, a technique which requires markedly different processing techniques to shearing. Particularly evocative were the samples of soay sheep wool that presenter Carol Christiansen brought to illustrate the distinctions between plucked and sheared fibre. Discussion after the session focused on how these processing techniques may have parallels in the archaeological record. Polina Medvedeva used textiles and textile impressions to investigate rapid social change in the Ural-Kazakhstan region from the first half of the second millennium BCE. Following this, Krista Vajanto presented her findings from Migration period Snartemo, Norway, which included the use of incredibly fine wool. The use of naturally pigmented fibres as well as natural dyes was suggested, with examination of the textiles by ultra high performance liquid chromatography finding no evidence of dye stuff for the reddish yarns. This finding prompted much discussion and debate among others who had similar results for red fibres in their own material.

Splicing was the theme of the day in the plant fibre procurement and processing session, chaired by Frances Pritchard. The first two papers highlighted the widespread use of the technique throughout the ancient world. Hero Granger-Taylor's presentation of her use of ethnographic parallels to understand the method of splicing in ancient Egyptian textiles prompted excitement during the discussion. Margarita Gleba and Susanna Harris then continued the session by presenting their own findings of spliced fibres from the exceptionally well-preserved Must Farm settlement, at which it is possible for the first time to see the complete *chaîne opératoire* of fibre processing and textile production from a Bronze Age site. The session was concluded by Johanna Banck-Burgess who discussed the THEFBO research project (see this ATR, 122-127) and the shift from the use of bast fibres to wool in the Neolithic settlement Hornstaad-Hörnle IA, Germany. She highlighted how consolidants used on these fibres have hindered analysis and ascertaining how reversible these treatments might be is a challenge.

The first session of day two, chaired by Frances Lennard, focused exclusively on fibres and textiles of the New World, and began with Camila Alday's study of the textiles used by ancient hunter-gatherer societies from the Atacama Desert of coastal South America. Her research indicated the use of underappreciated plant sources, notably from wetland areas, which have previously been overshadowed by the more widespread study of cotton. A similar theme was also evident in Liz Hammond-Kaarremaa's study of Coast Salish textiles from the Pacific Northwest, which indicated more widespread use of fibres such as the Salish Wooly Dog and fireweed fluff, especially in blended fibres, which have previously gone undetected. In consecutive papers by Thomas Connolly and Elizabeth Kallenbach, recent re-evaluation and updated radiocarbon 14 dating of objects in museum collections from the Great Basin region (where the extreme aridity has preserved a range of basketry items including vessels, nets, and footwear) saw a continuation of techniques despite movements of people spanning the Early-Late Holocene. All of the session's presentations echoed the theme established the previous day - that re-evaluation of artefacts, especially with the new techniques available to us today, is invaluable to the understanding of early fibres.

After a break for tea and another chance to view posters, Krista Vajanto chaired the penultimate session on fibres in the Middle Ages, which began with Riina Rammo's study of plant fibres in the eastern Baltic. While her results were preliminary, her paper highlighted how a combined approach, including phytoliths, longitudinal and cross-sections, and SEM analysis is necessary for accurate identification of bast fibres. María Martín Seijo talked about 14th to 16th century textiles from Pambre Castle in Spain, a region where textile survivals from this period are rare. Both wool and bast, and likely flax fibre, were identified on the interior of plates from a brigandine. Git Skoglund discussed differences in fibre quality between male and female specimens of dioecious plants, such as hemp, highlighting the possibility that the fibres of male and female plants may have been used for distinct purposes. Discussion noted that the competition for light that arises from more crowded planting results in finer fibres, and that it may be possible to better determine past agricultural processes by examining fibre remains.

The presentations concluded with a session on ethnographic textiles. The use of Skype technology, allowing Catherine Smith to give her presentation from New Zealand, made this conference truly international. Her research highlighted the development of distinctly Maori textiles, developed because of early Polynesian settlers to New Zealand needing to adapt to native plant resources following the failure of their traditional crops. The final presentation by Chris Buckley discussed the use of plant materials such as ramie and leaf fibres in southeast Asia, which was of particular interest with the majority of textile research in Asia centering on silk. Chris brought some of his reference collection to the conference and attendees enjoyed the experience of seeing these textiles first-hand. His presentation emphasised the need for ethnographic documentation of the production of these textiles, especially as some techniques are now carried out only by a handful of individuals.

Kay Lacey, Ruth Gilbert and Johanna Banck-Burgess (left to right) examine tartan samples at The Weaver's Cottage, Kilbarchan (Image: Susanna Harris)

The conference was brought to a close by Susanna Harris, and followed by the ETSG annual general meeting. Attendees were then treated to a tour of the Centre for Textile Conservation, University of Glasgow, where second-year masters students were on hand to discuss current projects. The optional field trip the next day visited the Weaver's Cottage at Kilbarchan, as well as the new Victoria & Albert Museum and Verdant Works Jute Mill in Dundee. A fun, textile-filled day and conference was had by all.

By Emma Smith and Sarah Hudson

Household textiles (and production) in and beyond the Viking Age

5 September 2019, Bern, Switzerland

The session *Household Textiles in and beyond the Viking Age* (#155) at the Annual Meeting of the European Association of Archaeologists in Bern 2019 was organised by Eva Andersson Strand, Centre for Textile Research, Saxo institute, University of Copenhagen, Charlotte Hedenstierna-Jonson, Uppsala University and Swedish History Museum, and Marianne Vedeler, Museum of Cultural History, University of Oslo. It aimed to explore the variety, function and production of household textiles in the Viking Age. The main discussion topic was: *What can be considered to be household production and what goes beyond it?* Although it is well known that cloth cultures had an important impact on societal development, this perspective is yet to be fully integrated into the general discussion of the social, economic and cultural changes that took place during the Viking Age and beyond. In general, most textiles produced in the Viking Age are considered to have been produced in a household context by women in their spare time. However, when the textiles are considered in a larger context, with estimations of resources, time and skill, their social impact becomes evident.

Charlotte Hedenstierna-Jonson presenting her paper at EAA 2019 session 155 (Image: Eva Andersson Strand)

To set the scene, the session began with an introduction to textile production focusing on the production chain from raw materials to finished cloth as well as time consumption. The presentations covered a wide range of different topics followed, such as the use of household textile furnishings (Eva Andersson Strand) and the tapestries from Oseberg (Marianne Vedeler); large-scale production of textiles at Bejsebakken and the presence of textiles in the garrison at the Viking town of Birka (Charlotte Hedenstierna-Jonson). The presentations also covered furnishings in burials such as mattresses and pillows (Charlotte Rimstad and Ulla Mannering), as well as the use of exclusive textiles such as tablet woven borders (Bente Skogsaas) and silk (Marie Bengtsson). The different presentations and the discussion clearly demonstrated the importance of building a more comprehensive overview of Viking cloth culture as a concept. Furthermore, it demonstrated that the interest and understanding of cloth culture is growing in the archaeology community.

By Eva Andersson Strand

Ancient textile production from an interdisciplinary Approach

7 September 2019, Bern, Switzerland

The full-day session *Ancient Textile Production from an Interdisciplinary Approach: Humanities and Natural Sciences Interwoven for Our Understanding of Textiles was held during the European Archaeological Associa*tion (EAA) conference in Bern, Switzerland, 4 to 7 September. The session organisers were Agata Ulanowska from the Institute of Archaeology (University of Warsaw, Poland), Karina Grömer, from the Natural History Museum (Vienna, Austria), Joanna Dyer from the British Museum (London, United Kingdom), and Ina Vanden Berghe from the Royal Institute for Cultural Heritage (KIK IRPA, Brussels, Belgium). The aim of this session (#133) was to review the current state of multidisciplinary approaches to the integrated study of archaeological textiles since the last comprehensive overview was published (Andersson Strand et al. 2010). By highlighting the possibilities new methods have brought to the study of ancient textiles, we can continue establishing frameworks for their study which incorporates a wide array of techniques. The session encouraged papers relating to anthropogenic modifications to fibrous materials, research relating to raw materials, scientific approaches to dyestuff analysis, including non-invasive techniques, textile and textile tool analysis, big data methods, and integrating the socioeconomic background with the interpretations and narratives we generate about the past. The wide geographical and temporal spread, from around the fourth millennium BCE to about 500 CE, and covering a large geographical area, from Europe and the Mediterranean, to the Near East and Asia, resulted in a wide range of interesting topics and methods of study.

The session began in the Middle East with two papers: the first by Karina Grömer (Natural History Museum, Vienna) and Ina Vanden Berghe (KIK IRPA Brussels), entitled “Achaemenid and Sasanid textiles and dyes from Ancient Persia. Case study Chehrābād in Northern Iran”. The focus of the research involved interdisciplinary approaches to the study of textile remains that included High-Performance Liquid Chromatography with Diode-Array Detection (HPLC-DAD) and Ultraviolet–visible spectroscopy (UV-Vis) absorbance spectra and retention times to determine the probable source of the plant and insect dyes used. The second paper “Blue and White along the Middle Nile: The Meroitic elites and their passion for indigo” was presented by Elsa Yvanez (Centre for Textile Research, University of Copenhagen, Denmark). The people in this region exhibited a preference for cotton textiles and the researchers explored the raw materials and applied HPLC with mass spectrometry to confirm the source of the blue dye. They also noted a possible connection to the West African indigo dyepots.

The next group of papers highlighted the non-invasive methods available for determining the origin of dye stuff on textiles. “A multispectral imaging (MSI) approach integrated into the study of archaeological textile collections at the British Museum” was presented by Joanna Dyer (British Museum, London). The next paper presented by Jocelyn Alcantara-Garcia (University of Delaware, United States), “Addressing the Challenges of Disassociated Archaeological textiles with multivariate classification of spectroscopic and chromatographic data”, described using Pre-Columbian Peruvian textiles without provenance as a reference collection. These methods of analysis can be used to trace chemical signatures to their point of origin. This new reference collection now serves as a comparative set for future identification of textiles for which the origin is unknown.

Following a discussion, the panel shifted its attention to raw materials. The first paper investigated flax cultivation via burnt remains and the creation of a morphometric rubric. It was entitled “Carboninsed Linseeds from Tel Burna, Israel. Flax cultivation intended for textile production?” and was presented by Andrea Orendi (Institute of Archaeological Sciences, Eberhard Karls University of Tübingen, Germany). The next paper described a blind test check for determining the microfibrillar angle of plant fibres to determine accuracy rates among technicians. This paper, “Blind testing: an evaluation of plant fibre diagnostic features”, was presented by Denis Wauby (University of Bradford, United Kingdom). The final paper, “Singular determination of the malacological provenance of royal purple”, delivered by Zvi Koren

(The Edelstein Center for the Analysis of Ancient Artifacts; Department of Chemical Engineering, Shenkar College of Engineering, Design and Art, Ramat Gan, Israel), explained how HPLC was used to confirm the source of archaeological purple from the *trunculus* species because it is the only snail species with the monobromoindigo dye signature.

The last three papers of the morning involved detailed technical visual analysis of textiles with non-invasive techniques. Ina Vanden Berghe (KIK IRPA, Brussels, Belgium) presented the paper "New Opportunities for textile research using macro X-ray fluorescence scanning: the investigation of metal threads in a reliquary purse", which detailed a case study example where construction techniques could be made visible and the metal components identified. Barbara Köstner (University of Bonn, Deutsches Textilmuseum, Krefeld; Haus der Seidenkultur, Germany) presented some of her PhD research in the paper "Reconstructing Late Roman and Early Medieval silk samites from Egypt: Research on techniques and looms with a practical approach". This involved a detailed technical analysis of their construction and a non-invasive visual approach for examining the yarns, warp, weft, and mapping irregularities to understand how the loom was set up and to relate textile fragments where irregularities are consistent. The last paper, "Interdisciplinary methods and new perspectives on inscribed textiles: Christian 'tiraz'", was presented by Julia Galliker (University of Michigan, United States) and Helga Rösel-Mautendorfer (Inscribed Textile Research Team, Austria), drew on textual sources and craft perspectives to supply additional evidence to support the interpretation of textiles which destructive methods may not otherwise provide.

The afternoon papers began with Tina Boloti's (General Secretariat for Research and Technology, Hellenic Ministry of Education, Research and Religious Affairs, Greece) "Horizontal vs Vertical Loom = Tradition vs Innovation? The case of Koukonisi Settlement Lemnos Island in the North Eastern Aegean". This paper drew on the archaeological evidence of recent discoveries of loom weights which indicate a shift in technologies from the horizontal to the vertical loom as specialised textile production intensified. Gabriella Longhitano (University of Liverpool, United Kingdom) presented "Weaving traditions in Archaic Sicily: The case study of Portella Sant'Anna" and described how loom weights with variable masses might be used on the same warp-weighted loom and the cloth that could possibly be produced at Portella Sant'Anna. The final paper of this segment was "Combs for wool or combs for plant fibres? Experiments with reconstructed tools" presented by Sabine Karg (Free University of Berlin, Germany). She explored the validity of flax being combed using these tools and experimental work which showed their suitability to wool instead.

The mid-afternoon papers took on multiscalar approaches. Lorin Yann (INRAP, French National Institute for Preventive Archaeological Research) began with "Contribution of multiscalar studies to the definition of the place of textile crafts during protohistory" and featured a thoughtful discussion of textile tools reflected in imagery and other iconography to investigate the potential underlying links to weaving over time and space. The next paper "Visible tools, invisible craft: an analysis of textile tools across the Iron Age south coast", presented by Lewis Ferrero (University of Cambridge, United Kingdom) assessed the spread of spindle whorls and loom weights along coastal sites in Britain to investigate whether craft organisation could be identified. Following this, Jennifer Beamer (University of Leicester, United Kingdom) presented the paper "Combing the data: assessing the utility of 'weaving' combs in the textile production sequence during the British Iron Age" which discussed the viability of long-handled combs in the textile production sequence and highlighted a rubric of recording metrics to explore their functionality.

The last three papers linked textiles with other objects. Zlata Blazheska (an independent researcher) explored textile impressions on pottery and identified a range of cloth types, and also considered their methods of manufacture in a paper entitled "Textile impressions from the Neolithic settlements in North Macedonia". The paper "Textiles and Seals: investigating relations between textile production and seals and sealing practices in Bronze Age Greece using statistical methods" was presented by Agata Ulanowksa (Institute of Archaeology, University of Warsaw, Poland), which examined the relationship between textiles, seals, and iconography, and described the database for housing these records. She also illustrated the comparative analysis that the database enables. The closing paper "From use wear to user: how literary sources can help understand Graeco-Roman textile tools" was presented by Magdalena Öhrman (University of Wales, Trinity Saint David, United Kingdom). This paper linked textile tools with contemporary ancient literary sources that discuss them, identifying use-wear that is textually embedded with the physical archaeological objects.

There was one poster submission by Elsa Yvanez (University of Copenhagen, Denmark), "Nubian openworks: tracking a local textile tradition through the ages", which used experimental methods to explore decorative open work techniques which were originally hypothesised by Elisabeth Crowfoot and Nettie Adams.

Bibliography
Andersson Strand, E. A., Frei, K. M., Gleba, M., Mannering, U., Nosch, M. L., & Skals, I. (2010) Old Textiles - New Possibilities. *European Journal of Archaeology.* 13, 2, 149-173.

By Jennifer Beamer

Silk in Ancient Greece and its resonance

19-22 September 2019, Athens, Greece

A four-day symposium on *Silk in Ancient Greece and its Resonance* was organised by Jenny Wallensten, Director of the Swedish Institute, Athens, Peder Flemestad at University of Lund, Sweden and Stella Spantidaki, director of ARTEX and University of the Aegean. The interest was such that the event had to be moved to larger premises and took place at the Scuola Archaeologica Italiana di Atene.

The symposium focused on new research on ancient silk across a broad spectrum ranging from the Aegean Bronze Age to Classical Athens, Rome, Byzantium and Viking Age Scandinavia. It also highlighted new scientific analyses as well as experimental work and reconstructions. A wide range of researchers representing different fields were invited to present their work in five sessions. On the first day, and after a short introduction and welcome by the organisers, Berit Hildebrandt opened the symposium with a keynote speech on the theme *The Provenance, Production and Manufacture of Silk in Ancient Greece: A Reassessment.*

The first session, *A Literary Thread*, focused on different texts such as *the Second Sophistic, The Evidence of Silk in Papyrus Texts from Egypt* and *The Use and Misuse of Silk in Late Antique Authors*. One of several question raised in the discussion was whether the authors of these texts really knew about silk and its processing or if they wrote about a material they had heard about but never seen. The general consensus among the participants was that the authors in antiquity could have invented their descriptions and that these cannot always be considered trustworthy. The session stimulated a debate about provenance and the origins of silk production in Greece and the eastern Mediterranean. This discussion continued into the second session, *A Historical Thread I,* in which evidence for silk in the *Byzantine World, The Culture of Silk in the Mamluks (13th to 16th centuries CE)* and *Silk in Cyprus Yesterday and Today: A Retrospective Exposé* were presented. In the third and last session this day, *A Historical Thread II*, the focus turned to northern Europe with silk finds from the Alps and Viking Age Scandinavia. Particularly interesting was the presentation of tablet-woven bands dated to the fifth to sixth centuries from Sweden. Some of these bands are woven with horsehair, which is interpreted as imitation silk. Prepared horsehair has the same lustre as silk and can be dyed with plant dyes. This opened a discussion about the possibility of fake silk in general, a phenomenon which may have been more common than hitherto thought.

The next day, new scientific analyses were presented in session four: *A Material Thread.* In the paper *From Cocoon to Textile: Structure and Colour,* a new method for distinguishing wild silk from cultivated silk using its natural fluorescence was introduced. This method is very promising and will clearly produce new perspectives on the introduction and use of different types of silk. The presentation on *Wild Silk from the Aegean: An Archaeoentomological Perspective* again brought up the question of when and if silk was used earlier than previously thought – in the Aegean Bronze Age. However, it was noteworthy that the general opinion was that there is still a lack of evidence and more finds are needed for this conclusion. New research and experiments were presented in *The Effects of Artificial Degradation on Silk Fibres.* The new tests clearly demonstrated that silk can be surprisingly well preserved if simply buried. However, if mineralised and carbonised, the fibres will be totally destroyed.

In the final session, *Tying Up the Threads*, new analyses of a unique silk tapestry with decorative patterns from Thessaloniki dated to the fourth century BCE were presented. The reconstruction work clearly shows the complexity of production and its extreme time consumption. It took five hours to weave 1 mm

Conference attendees (Image: Eva Andersson Strand)

of fabric with small patterns and four hours to weave 1 mm with larger patterns. In addition, the use of experimental methods in general was discussed.

On the last day, all speakers travelled together to Soufli, the silk capital of northeastern Greece, where its production has a long history dating from the Byzantine period. Soufli is said to be the only town in Europe which still processes silk from a cocoon to a finished product today. Even if the production is not as comprehensive as it was in the 19th century, it is clear walking around the city that Soufli still has a living craft with several smaller industries, shops and museums. During the day, the group visited several interesting places, among them the Silk Museum, housed in a late-19th century bourgeois mansion. The museum presents all the different phases and stages of pre-industrial sericulture and silk manufacturing. A workshop was also arranged for the symposium participants. The museum staff demonstrated how to reel the filaments from the cocoons with the aid of hot water. Everyone had the opportunity to try this technique, which was much appreciated; it is evident that hands-on experience always provides a better understanding of process. Two of the symposium participants, Amica Sundström and Maria Neijman, demonstrated how to dye with an indigo vat which they had brought from Sweden. They also showed silk yarns dyed with other plants such as saffron, cochineal and madder, demonstrating very clear and colorful hues which are possible when dyeing silk fibres.

The decision to combine scholars and experts from different research fields such as archaeology, history and philology as well as science and craft clearly demonstrated the value and importance of this symposium. It made the discussion lively and new knowledge was shared in research areas which might not otherwise be so easily accessible. Combining theory with practice also made this symposium a great success. The lectures showed the importance of silk in general and the practical sessions clearly demonstrated the complexity of producing silk textiles across all time periods and regions.

By Eva Andersson Strand

Recent publications

Creativity in the Bronze Age: Understanding Innovation in Pottery, Textile, and Metalwork Production **(2018) by Lise Bender Jørgensen, Joanna Sofaer and Marie Louise Stig Sørensen. Cambridge University Press**
Creativity is an integral part of human history, yet most studies focus on the modern era, leaving unresolved questions about the formative role that creativity has played in the past. This book explores the fundamental nature of creativity in the European Bronze Age. Considering developments in crafts that we take for granted today, such as pottery, textiles, and metalwork, the volume compares and contrasts various aspects of their development, from the construction of the materials themselves, through the production processes, to the design and effects deployed in finished objects. It explores how creativity is closely related to changes in material culture, how it directs responses to the new and unfamiliar, and how it has resulted in changes to familiar things and practices. Written by an international team of scholars, the case studies in this volume consider wider issues and provide detailed insights into creative solutions found in specific objects.
ISBN: 9781108421362
£ 75,00
https://www.cambridge.org/at/academic/subjects/archaeology/archaeology-europe-and-near-and-middle-east/creativity-bronze-age-understanding-innovation-pottery-textile-and-metalwork-production?format=HB

Dressing the Scottish Court, 1543-1553: Clothing in the Accounts of the Lord High Treasurer of Scotland **(2019) by Melanie Schuessler Bond. Boydell Press**
Analysis of accounts disbursed by the royal treasury, alongside text and translation in excerpt, provides richly detailed information on clothing at the time.
The Accounts of the Lord High Treasurer of Scotland document money spent by the royal treasury and contain numerous references to clothing and textiles. This volume is designed to make the rich material in the Accounts from the regency of the Earl of Arran (whose ward was Mary Queen of Scots) available to those interested in the study of dress and accessories. In addition to overviews of the various types of garments mentioned in the Accounts and discussion of a number of specialty categories, such as wedding and funeral clothing, this book includes the original text of every entry from the Accounts pertaining to secular clothing, with facing translation into modern English.
The Accounts' entries include information on materials and labour, and describe thousands of items for dozens of people, from court fools to nobles. They are grouped here by recipient, in "wardrobe biographies" which gather all of the entries for a particular person together in chronological order. Through the numerous clothing-related entries from this period it is possible to track the wardrobes of a number of people connected to the Scottish court, the popularity of various garments and accessories, details about their construction, and insights into the relationships of the people involved.
ISBN: 9781783272624
£ 75.00
https://boydellandbrewer.com/dressing-the-scottish-court-1543-1553-hb.html

Fighting Fibres: Kiribati Armour and Museum Collections **(2018) edited by Julie Adams, Polly Bence and Alison Clark Leiden. Sidestone Press Academics**
This book brings together artists, curators, researchers and conservators to consider the significance of coconut fibre armour from the islands of Kiribati. Taking as its focus the armour found in museum collections, it investigates the historical context that led to these unique artefacts leaving the Pacific and entering the orbit of British collectors and institutions, as well the legacies of those practices in the present.
As well as exploring the historical milieux surrounding its collection, the book includes essays from expert conservators that discuss the challenges of caring for coconut fibre armour. Other contributions include case studies focusing on the construction and variety of the armour and helmets, and the findings of a comprehensive survey which has tracked down and documented every piece of Kiribati armour held in

UK museum collections. Finally, the book considers the significance of coconut fibre armour in the present, with particular reference to the work of a group of I-Kiribati artists whose creativity and innovative research has led to the production of a contemporary suit of armour inspired by the armour of the past.
ISBN-13: 9789088905650
€ 39,95
https://www.sidestone.com/books/fighting-fibres

***Gaben, Waren und Tribute. Stoffkreisläufe und antike Textilökonomie* (2019) edited by Beate Wagner-Hasel and Marie-Louise B. Nosch. Verlag Franz Steiner**
Feine Wolle, Purpurfarben, exotische Gewänder, Leinen- und Seidenstoffe waren in der Antike begehrte Güter. Auf sie zugreifen zu können, war seit der Bronzezeit bis in die Spätantike hinein eine wesentliche Machtressource. Der älteste Seefahrermythos der Griechen, die Suche der Argonauten nach dem goldenen Vlies, erzählt davon ebenso wie spätantike Gesetze, die dem römischen Kaiser das Ankaufmonopol für Seide sicherten. Textilien zirkulierten über weite Räume als Gastgeschenke, Tribut-leistung, Handels- und Beutegut; in sozialen Netzwerken fungierten sie als Identitäts- und Erinnerungszeichen. Die Autorinnen und Autoren bringen in diesem Band die Perspektiven verschiedener Disziplinen zusammen, etwa der Mykenologie, der Archäologie, der Alten Geschichte, der Klassischen Philologie und der Philosophie. In ihren Beiträgen verfolgen sie diese textilen Güter auf ihrem Weg durch verschiedene Räume und Zeitläufte und nehmen ihre verschiedenartigen Gebrauchsweisen in den Blick. So hatten textile Techniken beispielsweise auch Auswirkungen in andere Künste wie der Vasenmalerei und der Bauornamentik und hinterließen auf diese Weise eine Anschauung von der Wirkung textiler Kunstwerke, die selbst nicht mehr erhalten sind.
ISBN: 978-3-515-12257-3
€ 76,00
http://www.steiner-verlag.de/reihe/view/titel/61646.html

***Medieval Clothing and Textiles 15* (2019) edited by Robin Netherton, Gale R. Owen-Crocker and Monica L. Wright. Boydell Press**
The best new research on medieval clothing and textiles, drawing from a variety of angles and approaches. The essays in this volume continue the Journal's tradition of groundbreaking interdisciplinary work. The volume opens with a survey of the discipline of medieval clothing and textiles, written by founding editor Gale R. Owen-Crocker. The range of the other essays extends chronologically from the early Middle Ages through the fifteenth century and covers a variety of disciplines. Topics include the conception of the author as a "wordweaver" in the literatures of Anglo-Saxon England; intertextual literary identities established through clothing in the Nibelungenlied and the Völsunga Saga; the historical record of clothing and textiles at the court of King John of England; medallion silks, their use in Western Europe, and their representation in art; the vestments of Beguines and other penitential movements in the thirteenth and fourteenth centuries; and a depiction of heraldic textile weaving in late-medieval art.
ISBN: 9781783274123
£ 40.00
https://boydellandbrewer.com/medieval-clothing-and-textiles-15-hb.html

***Medieval Clothing and Textiles 16* (2020) by Robin Netherton and Gale R. Owen-Crocker, edited by Monica L. Wright. Boydell Press**
The best new research on medieval clothing and textiles, drawing from a range of disciplines.
Following the Journal's tradition of drawing on a range of disciplines, the essays here also extend chronologically from the tenth through the sixteenth century and cover a wide geography: from Scandinavia to Spain, with stops in England and the Low Countries. They include an examination of the lexical items for banners in Beowulf, evidence of the use of curved template for the composition in the Bayeux Tapestry, a discussion of medieval cultivation of hemp for use in textiles in Sweden, a reading of the character of Lady Mede (Piers Plowman) in the context of costume history, the historical context of the Spanish verdugados (in English, the farthingale) and its use as political propaganda, an analysis of the sartorial imagery on a tabletop painting (attributed to Bosch) depicting the Seven Deadly Sins, and the reconstruction of one of the sixteenth-century London Livery companies' crowns.
ISBN: 9781783275151
£ 40.00
https://boydellandbrewer.com/medieval-clothing-and-textiles-16-hb.html

***Refashioning Medieval and Early Modern Dress: A Tribute to Robin Netherton* (2019) edited by Gale R. Owen-Crocker and Maren Clegg Hyer. Boydell Press**
Essays on costume, fabric and clothing in the Middle Ages and beyond. All those who work with historical dress and textiles must in some way re-fashion them. This fundamental concept is developed and addressed

by the articles collected here, ranging over issues of gender, status and power. Topics include: the repurposing and transformation of material items for purposes of religion, memorialisation, restoration and display; attempts to regulate dress, both ecclesiastical and secular, the reasons for it and the refashioning which was both a result and a reaction; conventional ways in which dress was used to characterise children, and their transition into young men; how symbolism-laded dress items could indicate political/religious affiliations; ways in which allegorical, biblical and historical figures were depicted in art in dress familiar to the viewers of their own era, and the emotive and intellectual responses to these costumes the artists sought to elicit; and the use of clothing in medieval literature (often rich, exotic or unique) as narrative, structuring and rhetorical devices.

Taken together, they honour the costume historian and editor Robin Netherton, who has been hugely influential in the development of medieval and Renaissance dress and textile studies.

ISBN: 9781783274741

£ 75.00

https://boydellandbrewer.com/refashioning-medieval-and-early-modern-dress-hb.html

***Textile Production and the Social Importance of Women in the Neolithic* (2019) by Marie-Lorraine Pipes, Janusz Kruk and Sarunas Milisauskas. Publisher: Instytut Archeologii i Etnologii PAN**

The study presents the results of the analysis of textile tools from Bronocice in Poland (3900-2800 BC, Funnel Beaker, Lublin-Volhynian and Baden Cultures). Numerous textile tools such as spindle whorls, loom weights and spools were recovered during the excavations conducted 1974-1978 by the State University of New York at Buffalo and the Polish Academy of Sciences. The objectives of the research are twofold: 1) to investigate the prehistoric environments, chronologies, economies, settlement systems and social organisation of the Funnel Beaker and Baden communities, and 2) to demonstrate the origin of complex societies in that region. A complex settlement pattern was uncovered at Bronocice consisting of storage pits, houses, ovens, fortification ditches and burials. Among the artefacts, the textile tools and faunal remains are in focus. In this study, the archaeological evidence is also interpreted by use of historical documents from other cultures and later periods.

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44 PLN

https://akademicka.pl/index.php?detale=1&a=2&id=99013613&lang=en

***The Ancient Egyptian Footwear Project: Final Archaeological Analysis* (2019) by Andreé J. Veldmeijer. Leiden. Sidestone Press Academics**

The Ancient Egyptian Footwear Project (AEFP) is a multidisciplinary, ongoing research of footwear in ancient Egypt from the Predynastic through the Ottoman Periods. It consists of the study of actual examples of footwear, augmented by pictorial and textual evidence.

This volume evaluates, summarises and discusses the results of the study of footwear carried out by the AEFP for the last 10 years (which includes the objects in the major collections in the world, such as the Egyptian Museum in Cairo, the British Museum in London and the Metropolitan Museum in New York, as well as from various excavations, such as Amarna, Elephantine and Dra Abu el-Naga). All published material is depicted and some previously unpublished material is added here.

The work on physical examples of footwear has brought to light exciting new insights into ancient Egyptian technology and craftsmanship (including its development but also in the relationships of various footwear categories and their origin), establishing and refining the dating of technologies and styles of footwear, the diversity of footwear, provided a means of identification of provenance for unprovenanced examples, and the relationship between footwear and socio-economic status. The archaeometrical research has lead to the reinterpretation of ancient Egyptian words for various vegetal materials, such as papyrus.

ISBN-13: 9789088907326

Price: EUR 49,95

https://www.sidestone.com/books/the-ancient-egyptian-footwear-project

***The Oseberg Tapestries* (2019) by Marianne Vedeler. Scandinavian Academic Press**

In 1904, a large burial mound was excavated at Oseberg in eastern Norway. More than 80 fragments of narrow tapestries patterned with figural motifs were among the unearthed artifacts. The exquisitely woven tapestries depict a myriad of finely shaped animals, humans, carriages, and houses. We can see battle scenes, warriors portrayed as animals, and hanged men as well as solemn processions. Part of the symbolism of these images can be linked to the warrior ideology and its surrounding myths during the Viking Age. Past and present, magic and politics are woven together, presenting powerful stories. The unique tapestries from Oseberg give us a window into the Viking of Age worldview that cannot be found elsewhere.

ISBN: 9788230402436
NOK 349,00
https://scandinavianacademicpress.no/boker/the-oseberg-tapestries

***The Textile Revolution in Bronze Age Europe: Production, Specialisation, Consumption* (2019) edited by Serena Sabatini and Sophie Bergerbrant. Cambridge University Press**

Textile production and the introduction of wool and woolen textiles represented a great revolution in Bronze Age Europe at the dawn of the second millennium BC. The available contemporary written sources from the Mediterranean and Near East suggest that textile production had a strong impact on the cultural, social, and economic life. In most parts of continental Europe, however, archaeological material alone can help us understand the details relating to textile production and its wider importance to early societies. This book provides new insights on patterns of production, specialization, and consumption of textiles in Europe throughout the Bronze Age. Assembling a diverse array of studies on various aspect of the textile production and economy. The essays, specially written for this volume, provide a wide range of scientific data as well as archaeological evidence. They also show the great potential of examining early textile production through the use of innovative methodologies and diverse perspectives.
ISBN: 9781108493598
£ 74,99
https://www.cambridge.org/at/academic/subjects/archaeology/archaeology-europe-and-near-and-middle-east/textile-revolution-bronze-age-europe-production-specialisation-consumption?format=HB

***Wool Economy in the Ancient Near East and the Aegean: From the Beginnings of Sheep Husbandry to Institutional Textile Industry* (in press) edited by Cécile Michel and Catherine Breniquet. Oxbow books, Ancient Textiles Series 17**

The history of the Ancient Near East covers a huge chronological frame, from the first pictographic texts of the late 4th millennium to the conquest of Alexander the Great in 333 BC. During these millennia, different societies developed in a changing landscape where sheep (and their wool) always played an important economic role. The 22 papers presented here explore the place of wool in the ancient economy of the region, where large-scale textile production began during the second half of the 3rd millennium. By placing emphasis on the development of multi-disciplinary methodologies, experimentation and use of archaeological evidence combined with ancient textual sources, the wide-ranging contributions explore a number of key themes. These include: the first uses of wool in textile manufacture and organization of weaving; trade and exchange; the role of wool in institutionalized economies; and the reconstruction of the processes that led to this first form of industry in Antiquity. The numerous archaeological and written sources provide an enormous amount of data on wool, textile crafts, and clothing and these inter-disciplinary studies are beginning to present a comprehensive picture of the economic and cultural impact of woollen textiles and textile manufacturing on formative ancient societies.
ISBN: 9781789253801
£ 28,00
https://www.oxbowbooks.com/oxbow/wool-economy-in-the-ancient-near-east-and-the-aegean-61017.html

Habilitation

Karina Grömer, who works in textile archaeology at the Natural History Museum Vienna, has qualified as *Doctor habilitatus* and awarded the title of *Privatdozentin* by the academic senate of the Faculty of Humanities at the University of Vienna, Austria. She is now approved to teach (venia docendi) in the academic discipline of Prehistory and Historical Archaeology.

Her thesis, *Archaeological textile research – technical, economic and social aspects of textile production and clothing from the Neolithic to the Early Modern Era*, reflects two decades of applied research on archaeological textiles and related sources. Karina's aim is to improve understanding of the role of textile production and textile products in the history of humankind. She argues that embedding finds and their context information in socioeconomic and cultural discourse contributes to the cultural anthropology of textile use. Besides textile technology, other important aspects of her research are about function, resource management, dress and identity, as well as creativity and design.

PhDs

Gabriella Longhitano was awarded a PhD by the University of Liverpool, Great Britain for her dissertation *Textile activity and its tools: indicators of cultural identities and interaction processes in Sicily and the Aeolian islands*. She investigated the traditions of making and using textile tools in Sicily between the 13th and the fifth centuries BC and the impact of cultural contacts on the indigenous traditions.

Errata

In *Unravelling the confusions: Defining concepts to record archaeological and historical evidence for knitting* by Jane Malcolm-Davies, Ruth Gilbert and Susanne Lervad, *Archaeological Textiles Review* 60, the same error in the cover factor calculation was repeated in Table 2, page 14 and on page 18.

The cover factor calculation is based on Pierce's (1937) and Russell's (1965) works on cover factor calculations, and Hammarlund's application of them (2005) to woven cloth. There is a much more complex cover factor calculation used in modern textile production process engineering, which has been applied to knitted fabric by Chen et al. (2004).
The cover factor is the ratio of the area covered by the yarn to the total area covered by the fabric:
WA + WE – (WA x WE)
WA = warp thread count per cm x yarn diameter in cm
WE = weft thread count per cm x yarn diameter per cm
The theoretical maximum density is 1. A measure of 0.9 is very dense fabric. A measure of 0.1 is not dense at all.
To convert this for use with knitted fabric:
(W per cm x YD in cm) + (C per cm x YD in cm) **MINUS** (W per cm x YD in cm) x (C per cm x YD in cm)
W = wales per cm x yarn diameter in cm
C = courses per cm x yarn diameter in cm
It is important to note the standard units of measurement must match for the ratio to be correctly calculated.
Note too that the "minus" symbol was incorrectly recorded in ATR 60 as a "divided by" symbol.

In Table 2 (page 14) and page 18, "loop density" is included as a measurement of the knitted fabric. This is an alternative way of recording the gauge of the fabric. The text did not adequately explain that these are alternative rather than different measurements.

Bibliography

Chen, Q., Au, K., Yuen, C. & Yeung, K. (2004) An analysis of the felting shrinkage of plain knitted wool fabrics. In *Textile Research Journal*, May, 399-404.

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Jane Malcolm-Davies

General Information

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The *Archaeological Textiles Review* aims to provide a source of information relating to all aspects of archaeological textiles. Archaeological textiles from both prehistoric and historic periods and from all parts of the world are covered in the ATR's range of interests.

1. Contributions are accepted in English.

2. Contributions may include accounts of work in progress. This general category includes research/activities related to archaeological textiles from recent excavations or in museums/galleries. Projects may encompass technology and analysis, experimental archaeology, documentation, exhibition, conservation and storage. These contributions can be in the form of notes or longer feature articles.

3. Contributions may include announcements and reviews of exhibitions, seminars, conferences, special courses and lectures, information relating to current projects and any queries concerning the study of archaeological textiles. Bibliographical information on new books is particularly welcome.

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