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Research on waterlogged archaeological textiles preserved in the so-called singer's burial (AD 580) from Trossingen cemetery, Germany

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Abstract

The waterlogged textiles and other organic remains preserved in Grave 58 from Trossingen cemetery form one of the most substantial non-mineralized amounts of organic material known so far from early medieval times in Germany. Three of the proved textile types are of particular interest, because their execution as weft-faced compound tabby and as tapestry weaves attributes them most likely to Mediterranean workshops, which is further underlined by their Late Antique ^{14}C-date. The fibre material had encountered both natural deterioration, but also migration of elements from the waterlogged surroundings. A broad range of techniques were used to identify the fibers, including, including sample staining, different microscopic methods as well as spectroscopic investigations and will be presented in more detail.

Keywords: waterlogged archaeological fibres, early medieval textiles, fibre investigation methods, migration processes

Grave 58–the so-called singer's burial–from Trossingen cemetery–is one of the best-preserved early medieval burials known in Germany. It contains not only preserved wooden grave goods, but also the remains of textiles, fur, and leather. It was uncovered in winter 2001/2002 and is part of a larger early medieval cemetery, dating from late 6th to early 7th century. Trossingen cemetery lies directly underneath today's town, which is located between the Swabian Alb and the Black Forest in Southwest Germany. Due to a special geological formation, this area is characterized by waterlogging, which provides good conditions for the preservation of organic material in burial contexts. The on-site observation of an intact wooden grave chamber with more waterlogged wooden artefacts preserved inside led to the decision to perform a block lift, and continue the excavation under laboratory conditions. Subsequently, it was possible to uncover and conserve the construction elements of a bed-shaped coffin with a coffin lid made of two decorated planks, items of furniture, several wooden bowls, a candlestick, as well as parts of the weaponry (Theune-Großkopf 2006; 2010). Inside the coffin laid the skeleton of a man, who died aged 35–40. A fully intact lyre was placed on top of his left arm, and a spatha made of damask steel rested underneath his right arm. Strontium isotope analysis proves that the deceased was a local. The burial must have taken place in AD 580 according to dendrochronological data of several wooden artefacts (Theune-Großkopf 2010: 20–23).

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Figure 1. Skeleton from Grave 58 laying on bottom planks of the coffin covered with organic residues. The lyre and the spatha were already removed. (Photograph: Landesamt für Denkmalpflege im Regierungspräsidium Stuttgart, Archäologische Denkmalpflege Freiburg)

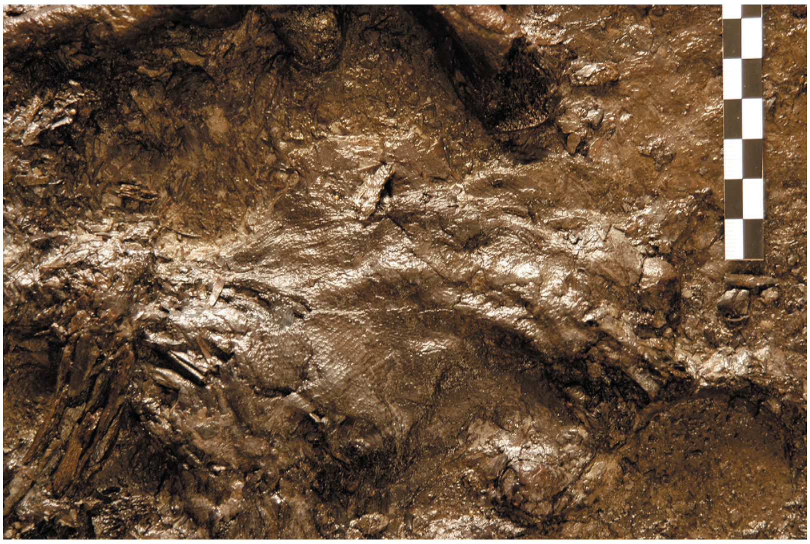

Figure 2. The organic materials are preserved in many compressed layers and show a brownish colour. (Photograph: Landesamt für Denkmalpflege im Regierungspräsidium Stuttgart, Archäologische Denkmalpflege Freiburg)

During the excavation of the block, it became clear that all of the bottom planks of the bed-shaped coffin, as well as parts of the skeleton, were covered with the waterlogged remains of different organic materials (Figure 1). They were preserved as compressed, multi-layered residues that turned a brownish colour during the storage in the soil (Figure 2). After *in situ* documentation, the organic residues were removed from the bottom planks as mini-blocks in order to perform more detailed microscopic investigations. The first investigations were performed directly after the excavation (Peek and Nowak-Böck 2016), while the entire analysis of the mini-blocks began later (Niepold, in preparation). The research revealed different textile types made of wool and plant fibre, several leather artefacts, fur, and archaeobotanical remains. The waterlogged mini-blocks were deep-frozen, and stored wrapped in several layers of PE-foil and PE-bags. This kept the remains in a condition that showed no extensive changes compared with the preservation status documented in 2002.

23.1. Waterlogged archaeological textiles – challenges in fibre investigation

A closer look at textile fibre samples from Grave 58 with Transmitted Light Microscopy (TLM) and Scanning Electron Microscopy (SEM) revealed the issues of identifying waterlogged archaeological fibres: most fibres lost specific surface features and underwent severe changes in fibre shape. While freeze-drying the waterlogged samples for investigation with SEM, the fibres collapsed and turned into flat strips or even amorphous masses (Figure 3). Wet sample preparation methods for TLM prevented a collapse of fibre structures, but the advanced stage of degradation hampered immediate fibre identification as well. Only after surveying many samples did certain characteristics of the degraded fibres become obvious and allowed for a determination: wool appeared as short, opaque bits with blurry outlines. In contrast, plant fibres showed as veil-like, transparent structures with more distinct outlines (Figure 4). Subsequently, different analysis methods were performed to cross-check these observations and to explore their potential for determining decomposed, waterlogged fibre samples in general. This encompassed simple staining tests and trials to prevent fibre collapse during drying, as well as determining specific fibre components by spectroscopic analyses.

23.1.1. TLM – sample staining

Fibre staining with the reagent chlor-zinc-iodine and the staining agent Shirlastain A® was tested to further underline the microscopic observations of plant fibres and wool by marking the presence or absence of specific fibre components. The reagent chlor-zinc-iodine turns cellulosic compounds in plant fibres like linen, hemp or cotton a dark blue colour (Luniak 1953: 95). However, none of the Trossingen plant fibre samples changed colour after application, which normally indicates a fibre containing no cellulose. In this case, the non-appearance points to the advanced degradation stage of the plant fibres. This must have prevented the incorporation of the iodine atoms into the fibre molecule structure, which normally causes the formation of a blue chemical complex. Shirlastain A® turns wool samples yellow and plant fibres different shades of red (Ford and Warwicker 1961). Regardless of whether the samples were wool or plant fibres, all took on the natural pinkish colour of the staining agent without showing fibre-specific colour changes after application time and rinsing. In this instance as well, the advanced fibre degradation must have prevented the required colour change. Both tests showed that staining techniques are inappropriate for determining degraded fibre samples from waterlogged surroundings, like those from Grave 58.

23.1.2. SEM – sample stabilising by bulking agents, consolidants, and fixative agents

The collapse of fibre structures as a consequence of sample drying for SEM-analysis also affected the determination of the degraded fibres. To obtain more informative SEM-images, the potential of bulking agents, consolidants, as well as fixative agents were tested to see which methods prevent fibre collapse and help fibres keep their characteristic shapes. All soaking solutions were applied to

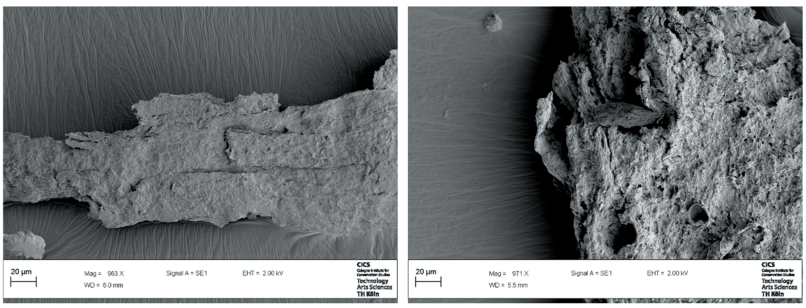

Figure 3. SEM-images of thread samples which show collapsed wool (left) and plant fibres (right). (Image: T. Niepold)

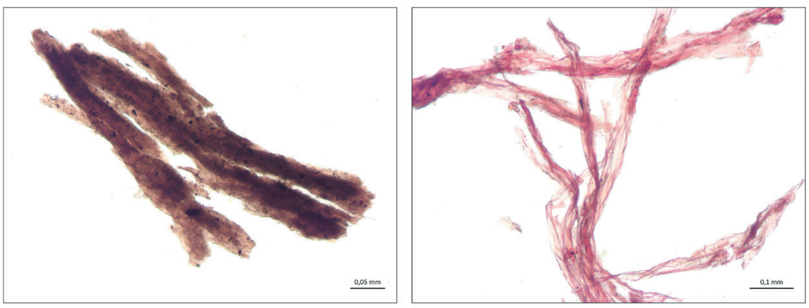

Figure 4. TLM-images of degraded wool (left) and red dyed plant fibres (right), mounted in water. (Image: T. Niepold)

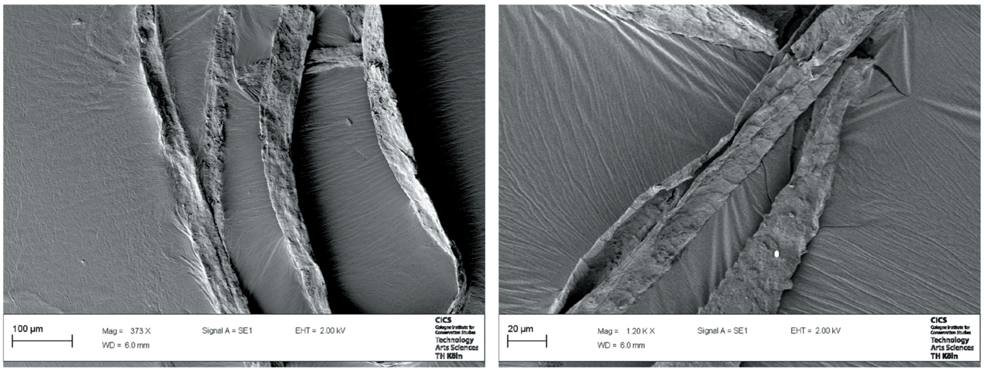

Figure 5. The application of diluted bulking agents (here left with PEG 400, 5%) and consolidants (here right with Methylcellulose, 1 %) did not prevent collapse of the test fibres (wool). PEG additionally assembled on the surfaces covering the scale structures. (Image: T. Niepold)

test fibres, which were taken from the same woollen textile preserved in Grave 58. These fibres were suitable as test materials due to the preserved scale structures which would make coating effects visible. After soaking, all test fibres were freeze-dried for SEM-analysis.

The Polymer Polyethylenglycole (PEG) is an important bulking agent for drying wet archaeological textiles (Peacock 2011: 366–367). PEGs with low molecular weights penetrate fibres to replace the incorporated water. SEM-images of the test fibres soaked in diluted PEG 400-solutions (5% and 10%) showed PEG unfortunately did not maintain fibres' shape and three-dimensionality, but coated the fibres' surfaces (Figure 5). This probably happened due to the plasticizing property of PEG, which caused an accumulation of the agent on the fibre surfaces. This effect becomes more obvious when comparing the PEG-treated fibres with samples soaked in a diluted consolidant solution (Methylcellulose, 1%), where the scale structure is still clearly visible. Beyond this, the application of the consolidant was not able to maintain the fibres' shapes. Other test fibres were treated with two different fixative agent solutions based on formaldehyde and glutaraldehyde (Mulisch 2015: 91). Both aldehydes induce an irreversible cross-linking of proteins, which was intended for preventing changes in shape and dimension of proteinoid sample material. However, the application of a solution of 1% formaldehyde and 2.5% glutaraldehyde as well as a solution of ethanol, formaldehyde, and acetic acid (9:0.5:0.5) did not fulfil these expectations and instead caused a severe harm to the fibres leaving hardly any part of the surfaces intact (Figure 6). Most likely, this damage was provoked by the ability of the aldehydes to act also as strong reducing agents, which probably led to a breakdown of chemical bondages within the protein molecules.

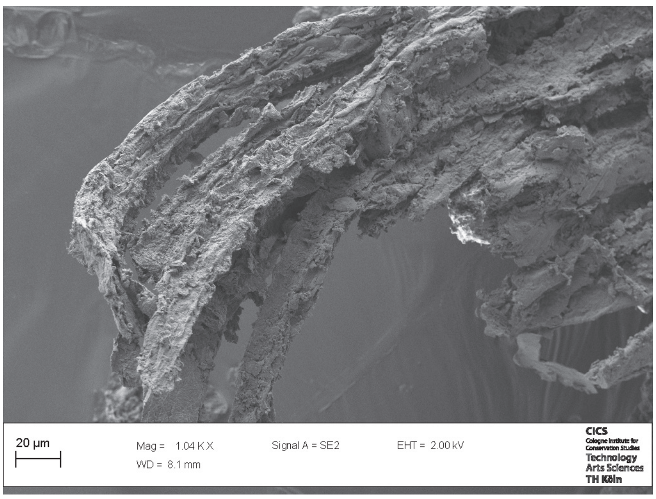

Figure 6. Soaking the test fibres (wool) with fixative agents (here 1 % formaldehyde and 2.5 % glutaraldehyde), meant to prevent fibre collapse by cross-linking proteinoid fibres, caused severe harm to the fibres. (Image: T. Niepold)

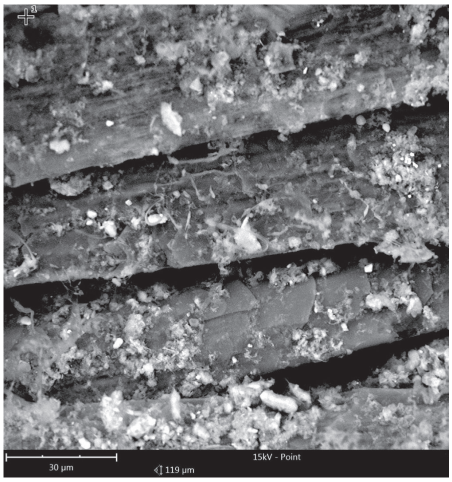

Figure 7. Test fibre (wool) on cooling stage. The maintained three-dimensional fibre structure allows for a thorough investigation of the fibre surface. (Image: T. Niepold)

23.1.3. SEM with cooling stage

As none of the soaking agents helped to preserve fibre structures while drying samples for SEM-analysis, special SEM-equipment which allows for the investigation of waterlogged, undried fibre samples was tested. This is achieved by deep-freezing the fibres on a cooling stage in combination with lowering or variating the pressure in the SEM vacuum chamber, which makes the evaporation of the frozen water controllable. This was the only process which was able to maintain fibre shapes and enabled a thorough investigation of the fibre surfaces. (Figure 7).

23.1.4. Detecting chemical fibre composition – SEM-EDX and FTIR-spectroscopy

For differentiating between highly degraded fibres, the detection of sulphur or nitrogen with SEM-EDX (Scanning electron microscopy with Energy dispersive X-ray spectroscopy) may provide further hints, as wool normally contains significantly higher amounts of both elements than plant fibres (Kuffner and Popescu 2012: 175–176). Certain elements like iron, copper or aluminium may also indicate the usage of metal salts as mordants in preparation for the dyeing processes. SEM-EDX is based on the interaction of the sample with the impinging electron beam, resulting in an element-specific X-ray emission spectrum. The EDX-spectra of all fibre samples from Grave 58 showed high rates of silica, aluminium, and iron, which were also visible in EDX-spectra of sediment particles, taken as reference from the burial soil. Therefore, no differentiation could be made between soil particles adhering to the samples and potential mordants. High amounts of sulphur and nitrogen were visible in EDX-spectra of wool and plant fibre samples, as well as in EDX-spectra of sediment particles. The overall presence of both elements in all samples made not only a reliable differentiation between plant fibres and wool impossible, but also speaks for contamination by sulphur-containing substances. They belong to protein components which result from corpse decomposition and penetrated into all organic materials and sediment layers. This observation points out the effect of migration processes, especially in waterlogged milieus which may influence the chemical composition of organic archaeological sample material.

This also became visible with FTIR-spectroscopy (Fourier-Transform-Infrared-Spectroscopy) which is based on specific interaction properties of molecular structures with impinging light. The resulting FTIR-spectrum shows the absorption of light at particular wavelengths, which is specific for certain functional groups and marks the presence of different chemical compounds in the sample material. All FTIR-spectra of fibre samples from Grave 58 were quite similar. They all showed the presence of both protein components and silica which prevented a differentiation between plant and protein fibres. The domination of both components in the spectra again pointed to the high impacts of the corpse decomposition products as well as the contamination by soil particles. Without more distinct sample preparation protocols and post-processing of the spectra, investigation methods focusing on the detection of certain elements or functional groups, like SEM-EDX or FTIR-spectroscopy, turned out to be unsuitable tools for determining highly degraded archaeological fibres like those from Trossingen cemetery.

23.2. Focusing on the textiles – a link to the past

Microscopic investigation of the mini-blocks from Grave 58, as well as the results of fibre determination, enabled the identification of ten different textile types made both of wool and plant fibres. The documentation of their distribution within the mini-blocks in planar and stratigraphical mappings revealed that the textiles once belonged to the deceased's clothing, a wrapping for the corpse as well as different parts of the coffin upholstery. Nevertheless, distinct shapes or cutting patterns were not reconstructable. The textile types involve tabby weaves, a twill weave, and a tablet weave. The presence of a weft-faced compound tabby is particularly noteworthy, as is the presence of two different tapestry weaves (Table 1). These finds are unusual for the majority of textile finds preserved in early medieval burials north of the Alps, and therefore are presented here in more detail.

Table 1. The remarkable textile types from Grave 58.

Weft-faced compound tabby	Tapestry weave type I	Tapestry weave type II
Warp: (main + binding warp) wool, z-spun, undyed (?), Ø ~0.4 mm Density: 12 binding warp yarns/cm Warp proportion: 1:1	**Warp**: wool, z-spun, undyed (?), Ø 0.8–0.9 mm Density: 4 yarns/cm	**Warp:** plant fibre, 2z/S, undyed, Ø 0.3–0.4 mm Density: 7–10 yarns/cm
Weft: wool, z-spun, bluish-purple and red, Ø ~0.4 mm Density: 30–40 passes/cm	**Weft**: wool, z-spun, reddish and dark, Ø 0.8–0.9 mm Density: 14 yarns/cm	**Weft:** wool, 2z/S, red and blue, Ø 0.3–0.4 mm; wool, undyed (?), z-spun, Ø 0.3–0.4 mm Density: 30–55 yarns/cm
Dyestuffs: Bluish-purple weft: indigotin as main component; dyestuff from madder group, most likely wild madder (*Rubia peregri-na* L.), as second component Red weft: duestuff from madder group, most likely wild madder (*Rubia peregrina* L.)	**Dyestuffs:** Reddish weft: dyestuff from madder group, most likely wild madder (*Rubia peregrina* L.), as main component; tannins as second component Dark weft: tannins as main component; dyestuff from madder group, most likely wild madder (*Rubia peregrina* L.), as second component or contamination	**Dyestuffs:** Red weft: dyestuff from madder group, most likely wild madder (*Rubia peregrina* L.)

23.2.1. Weft-faced compound tabby

The weft-faced compound tabby is made of wool, and shows a high thread count in the weft system with 30–40 passes per cm (Figure 8). The proportion of main warp to binding warp is 1:1. Two different colours were observed in the passes: red, and a yellowish colour. However, the results of dyestuff analysis showed that the visible yellowish colour was originally dyed blue with an indigotin-containing dyestuff (Bruselius Scharff and Maj 2011). Apart from indigotin as a main dyestuff component, a dyestuff of the madder group, most likely wild madder (*Rubia peregrina* L.), was detected as a second dyestuff component. Both dyestuffs were probably combined to produce a bluish-purple colour, but a contamination cannot be excluded. The red weft system was also dyed with a dyestuff from the madder group, again most likely wild madder (*Rubia peregrina* L.).

The weft-faced compound tabby fragments appear all over the grave, mostly in two or more adjacent layers. During the investigation, it became obvious that there is a padding layer in-between, which points to a padded textile. The padding layer consists of fine feather fragments mixed with grass or fine leaf strips. Some textile fragments show traces of seams. The remains of a hem with blanket stitches were only preserved in the leg and feet area of the grave, and mark cutting edges in the warp direction that had to be secured. Considering the approximate size of the weft-faced tabby based on the distribution of fragments within the grave and their stratigraphic position in the uppermost and lowest layers within the organic residues, it can be concluded that the padded textile was used to wrap the body.

The [14]C-analysis resulted in a dating between 259 and 480 cal. AD (2-sigma), which makes a production in Late Antique times most likely, and highlights that the textile was already old when it was used as wrapping for the deceased.

In early medieval burials north of the Alps, thus far weft-faced compound tabbies have been documented in a female burial in Belgium (Verhecken-Lammens et al. 2004: 57), in sarcophagi underneath St. Denis, Paris (Desrosiers 2015: 137–140), and at St. Victor, Marseille (Boyer 1987: 62–74). The last two examples are made of silk. This small number of comparable finds, in addition to the still missing proof of an appropriate weaving technology for producing complex weaves in early medieval times north of the Alps, speaks for a Mediterranean origin for the weft-faced compound tabby from Trossingen cemetery. Mediterranean evidence for these kinds of textiles exists as early as the 1st century AD in both written sources and archaeological finds. The earliest find comes from Berenike in Egypt (Wild and Wild 2000: 256–257), with another weft-faced compound tabby from 1st century AD found in Masada in Israel (Sheffer and Granger-Taylor 1994: 212–215). Ascribing the Trossingen weft-faced compound tabby to a Mediterranean workshop is further supported by its Late Antique date.

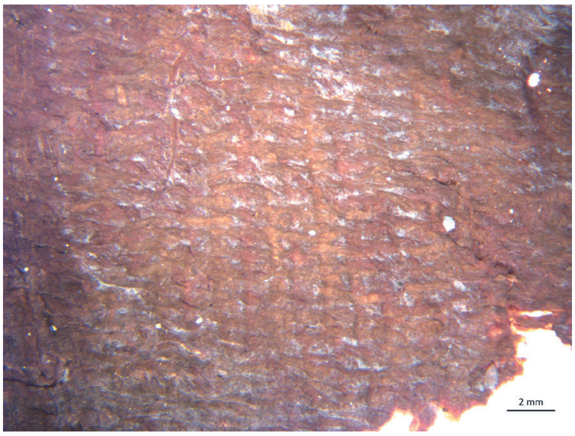

Figure 8. Brownish weft-faced compound tabby, originally patterned in bluish-purple and red. (Image: T. Niepold)

23.2.2. Tapestry weaves

The two tapestry weaves show significant differences between each other in terms of fibre materials and yarn construction. Tapestry weave type I is made entirely of wool, and shows thick z-spun warp and weft yarns. With fourteen weft yarns per cm, the tapestry weave has a coarse quality. Different shades of brown, distinguishable under magnification, indicate a patterned textile (Figure 9). The turning points of the weft threads prove the usage of tapestry weaving technique to craft the item.

Dyestuff analysis of samples taken from darker and reddish-appearing areas further underlined the observation of a patterned textile. The darker areas revealed tannins as the main dyestuff component, which suggests the yarns were dyed black. Traces of a dyestuff from the madder group, most likely wild madder (*Rubia peregrina* L.), were also detected. For the more reddish appearing areas, a dyestuff from the madder group, most likely wild madder (*Rubia peregrina* L.), was traceable as the main dyestuff component. The detection of tannins as a second dyestuff component indicates that yarns from this pattern area were dyed a dark red colour.

The planar distribution of the tapestry weaving is limited to the chest area of the skeleton. Here, it appears only in the uppermost layers of the organic residues. This observation indicates a single

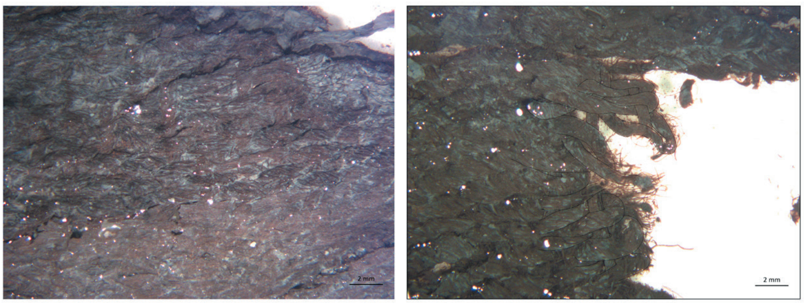

Figure 9. Tapestry weave type I with dark and reddish pattern area. Turning points of wefts threads (drawing) prove tapestry weaving technique. (Image: T. Niepold)

piece of tapestry weave of a limited size, which was placed for decorative or symbolic purpose on the upper body after wrapping the corpse with the padded weft-faced compound tabby. Cutting edges, selvedges, hems, and/or seams were not detected.

Tapestry weave type II has 2z/S-plied yarns made of plant fibres in the warp system and 2z/S-plied yarns made of wool in the weft system as well as single z-spun yarns (Figure 10). Wefts in different shades of red and blue in addition to a likely undyed yarn were observable. Compared to Tapestry weave type I, the weft system thread count is remarkably high, with up to 55 yarns per cm. Only one of the two red weft systems was examined for dyestuffs, which led to the detection of a dyestuff from the madder group, most likely wild madder (*Rubia peregrina* L.).

Tapestry weave type I fragments are limited to the area of the skull, where they always appear together with another textile made of plant fibres as well as archaeobotanical remains. Stratigraphical interrelationships indicate that the textiles once belonged to a pillowcase, which was stuffed with botanic material. Seams, stitches, or other processing marks could not be documented.

Tapestry weave type I and II have also been ^{14}C-dated, which gave a production date between 363 and 537 cal. AD (2-sigma, Type I) and between 403 and 539 cal. AD (2-sigma, Type II). Both of these datings show a great deal of uncertainties on the calibrated date and consequently a long time span of about 200 years, which is explained by a plateau in the ^{14}C-calibration curve between AD 450 and 550. In the context of the ^{14}C-dated weft-faced compound tabby, it is likely that both tapestry weaves were also made in Late Antique Times. To make sure that all ^{14}C-dates reflect sample ages and not components from soil storage, a simple plain weave from Grave 58 was ^{14}C-dated as well, which gave a production date between 537 and 635 cal. AD. Therefore, the presence of textiles in Grave 58, made during the lifetime of the deceased, proved the reliability of the results.

So far, only a few tapestry weave fragments were documented in early medieval burials north of the Alps. The tapestry weave fragments from a chieftain's burial in Poprad Matejovce, Slovakia, show very similar technological details to Tapestry weave I from Grave 58 (Štolcová et al. 2017). Close parallels to Tapestry weave II can be observed in tapestry weave fragments preserved as mineralized remnants in a child's grave in La Tour-de-Trême, Switzerland (Graenert and Rast-Eicher 2003: 167-170). As with the weft-faced compound tabbies, there is no proof so far that tapestry weaving was introduced into the textile traditions of Germanic regions in early medieval times. Therefore, it seems reasonable to ascribe the production of both tapestry weaves from Trossingen to workshops of the Mediterranean area workshops as well, where this textile technique had been known already for a long time. This assumption is further supported by their likely production in Late Antique Times. However, the z-spinning direction of the yarns as well as the coarseness of Tapestry weave type I make it difficult to find comparable pieces among the contemporaneous finds from the Mediterranean area. The same holds true for Tapestry weave type II with its 2z/S-plied warp yarns, as tapestry weaves with plied

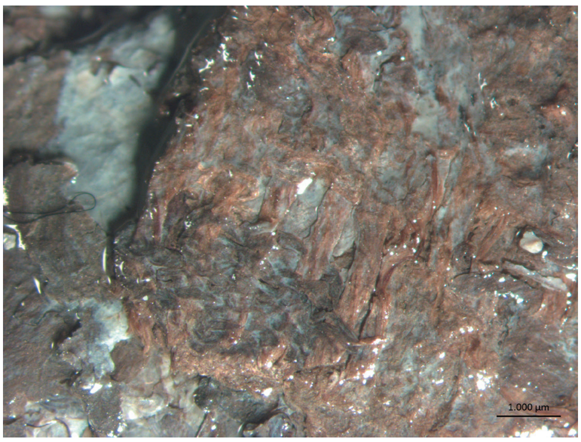

Figure 10. Tapestry weave II with plied 2z/S-warp threads and blue wool wefts. (Image: T. Niepold)

yarns appear in the Mediterranean area no earlier than the 7th century AD, and their plied yarns show a contrary construction (2s/Z). Further research could trace more closely the place of production of both tapestry weaves from Grave 58, as well as those from Poprad Matejovce and La Tour-de-Trême.

23.3. Conclusion and summary

The research on the waterlogged organic residues preserved in Grave 58 from Trossingen cemetery (AD 580) uncovered a wide range of textiles, leather, and fur fragments. Extraordinary among them are a weft-faced compound tabby and two different tapestry weaves. According to ^{14}C-dating results, all three textiles were most likely produced in Late Antique times and were already old when they were used for the burial. The early time of production as well as the observed textile techniques, for which there is no evidence in Germanic regions in early medieval times, strongly suggest Mediterranean workshops as their place of production. The weft-faced compound tabby was used as a padded wrapping for the corpse, and the two tapestry weaves acted as an uppermost decorative or even symbolic textile layer and as part of a pillowcase.

Fibre samples from all textiles preserved in Grave 58 showed an advanced stage of degradation under transmitted light microscopy (TLM) and scanning electron microscopy (SEM), and made fibre determination challenging. The results of fibre investigation methods presented in this paper highlight the need of several analysis methods when considering the fibre determination for degraded, waterlogged fibre samples. Problematic was also the particle migration in the waterlogged milieu. It caused the contamination of fibres that was detected by SEM-EDX and FTIR-spectroscopy.

The advanced fibre degradation also prevented sample staining from working. For the Trossingen fibre samples, TLM as well as SEM-analysis with cooling stage, which allows for the investigation of waterlogged samples, proved to be the most appropriate fibre determination methods.

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