Assessing the potential of historic archaeological collections: a pilot study of the British Museum’s Swiss lake dwelling textiles

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Summary
The British Museum houses a significant collection of organic material from prehistoric Swiss lake dwellings (c.4000 to 500 bc) excavated in the late nineteenth century. The waterlogged, anaerobic, alkaline burial environment provided conditions suitable for the preservation of a range of organic materials including many textiles. The textiles, which represent a range of techniques and include fine complex weaves, netting and skeins, largely remain as treated at the time of excavation. Recent assessment of the condition of this textile collection, with a view to improving the storage and display of these rare survivals, has allowed nineteenth-century approaches to the recovery, treatment, mounting and display of archaeological materials to be documented. The collection has been rehoused in a suitable standardized storage system, preserving the original and highly informative historic mounts. Some of the textiles remain, however, at risk due to acidic mounting materials, broken glass or the fragments being insecure in their frames. The opportunity was also taken to assess the potential of this historic textile collection for detailed investigation, including fibre identification, technological study and dye analysis. A range of analytical techniques was employed, including macroscopic analysis, scanning electron microscopy (SEM), Fourier transform infrared (FTIR) spectroscopy and Raman spectroscopy. Weave analysis and technological classification of the textiles was possible, even for textiles still in their original mounts. Many of the textiles showed signs of early consolidation and the presence of detrital material but, using SEM, fibre identification was possible in every sample examined. This demonstrated the use of flax fibres (Linum usitatissimum), lime/linden (Tilia sp.) bast fibres and lime/linden bark showing various degrees of processing. The majority of the fibres examined showed evidence for low temperature or incomplete charring. Using FTIR a range of consolidants has been identified, including natural resins and a carbohydrate material, possibly a gum or sugar solution. The chemical condition of some of the fibres, determined by Raman spectroscopy, and the presence of consolidants and other detrital material, suggests that potential dye analysis and other forms of (bio)molecular analysis could be compromised for some of the collection. The results of this pilot study will guide the future conservation strategy for this historic collection and allow informed decisions to be made regarding future access for technical and scientific study.

INTRODUCTION
The British Museum houses a significant collection of organic material from prehistoric Swiss lake dwellings dating from the Neolithic to the Bronze Age (c.4000 to 500 bc). This material comes from waterlogged settlements excavated from the shores of alpine lakes (the so-called lake dwellings or ‘pile structures’, Pfahlbauten in German) and represents some of the best examples of surviving perishable plant fibre-based artefacts in Europe [1]. The waterlogged, anaerobic, alkaline burial environment provided suitable conditions for the preservation of a range of organic materials such as wood, bone, antler, textiles and basketry made from plant fibres, as well as fruits, seeds and cereal grains. The first excavations were in the mid-nineteenth century and while the best-known sites are those from Switzerland, similar sites have been found in Germany, France, Italy and Austria. Much is known about the mid-nineteenth-century excavations from the work of the Swiss archaeologist Ferdinand Keller, whose reports to the Antiquarian Society of
Figure 1. Current condition of original glass mounts: (a) textile fragment from Robenhausen (1964,1201.1252) in a nineteenth-century mount showing the Messikommer label, blue tape and fragmentation of the textile within the frame; (b) a second textile fragment from Robenhausen (1964,1201.1252) originally in the Rosehill collection showing fragmentation of the textile, the poor condition of the tape and the irregular mount dimensions; and (c) fragment (1964,1201.1251) from an unknown findspot showing adhesion of the textile to the glass mount and the use of cork spacers. Scale bars show 1 cm divisions.
Zurich (Antiquarische Gesellschaft in Zürich, AGZ, which he had founded in 1832) between 1854 and 1866 were translated into English by John Edward Lee in 1866 [2, 3]. Compared with other types of archaeological finds/artefacts, the survival of textile materials is rare. This is partly because of the unusual environmental conditions required to preserve textiles and partly because, historically, less importance was placed on textiles in comparison to other classes of finds. Thus where textiles are preserved, they have not always been recovered or survived the recovery process, or may not have been the subject of subsequent research [4]. However, from the outset, the textiles from the lake dwelling excavations were considered remarkable for their quality, quantity and state of preservation, and numerous finds – including textiles – were sold to individuals and museums around the world [5]. Many lake dwelling artefacts were sold on the antiquities market, indicating that they were perceived not only to have scientific but also commercial value [6].

The British Museum and many other museum and university collections house examples of Swiss lake dwelling textiles, reflecting nineteenth-century interest in the material. While much has been learnt over the last 150 years about the excavation and treatment of wet archaeological materials, and archaeological conservation has developed as a conservation specialism, those collections that survive are often now sadly neglected and overlooked. Although some of the British Museum collection was on display from c.1890 until at least 1925, it has been in storage for many years [7, 8]. At the British Museum and elsewhere these important historic collections, although often poorly provenanced, are being reassessed to: (i) establish their condition and potential for detailed study, including fibre identification, technological analysis and research using other analytical approaches; (ii) improve understanding of, and access to, such collections; and (iii) document nineteenth-century approaches to the collection and display of archaeological material and the development of archaeological conservation.

**Background**

The c.100 textile fragments that entered the British Museum collections in a variety of ways are now housed in the Department of Prehistory and Europe. Although described collectively as textiles, these holdings comprise threads, cords, woven fabrics, twining, knotted netting and basketry fragments. Robenhausen, in the municipality of Wetzikon at the south end of Lake Pfäffikon in north east Switzerland, owned and excavated by Jacob Messikommer from 1858 onwards, is the main site represented in the British Museum collection. There is also a group of textiles acquired from the collection of Lord Rosehill, some of which were from Robenhausen [9]. Several textiles found in the nineteenth century at Robenhausen came from the Wellcome Institute of Medicine (acquired 1964) and John Edward Lee (acquired 1910). Other lake dwellings are represented, including Schaffis, Auvernier and Mörigen (all in Switzerland) and Wängen (Germany), but not all are provenanced to a specific site (some are simply labelled ‘Lac de Neuchâtel’ and ‘Lac de Pfäffikon’) and – as with many early excavations – there is little or no contextual information.

Keller describes much of the material recovered from the Swiss lake dwellings, particularly that from the Lake Pfäffikon sites, as burnt or charred and suggests that destruction of the predominantly wood and straw settlements by fire is likely to have occurred repeatedly [2, 3]. He further suggests that much of the material may have fallen into the waters of the lake and become buried in the mud before being totally consumed and converted to ash. However, Keller also notes that balls of string and pieces of cloth that are unburnt were also found “amongst the remains of conflagration” but that “when exposed to the air become so shrivelled and altered that their original form is hardly discernible” [2].

A 20-year correspondence between Keller and Messikommer (mainly relating to material from the Robenhausen site), preserved in the archives of the Swiss National Museum, provides a unique record of the early experiments in preserving the archaeological textiles [10]. From this
archive and work undertaken by Travis into the historical development of archaeological conservation, it is known that smaller two-dimensional textiles were probably air dried on site and simply sandwiched between plates of glass, with paper pasted over the edges [10, 11]. This approach has proved to be reasonably successful, especially for pieces believed to have been charred. Larger cloths and nets were harder to deal with and were often cut up into smaller fragments to make them easier to preserve and more saleable. Many of the Robenhausen textiles were dried and framed by Messikommer himself [11], but it is not known if any of these are included within the British Museum material, see Figure 1a. Correspondence between Keller and Messikommer in 1861, discussing pieces that were either ‘insufficiently conserved’ or ‘over-impregnated’, implies the use of consolidants [10, 11]. Travis has established a timeline of materials and methods used to treat lake dwelling materials and suggests that from the 1850s animal glue, copal varnish with turpentine or copal varnish and gelatine were used [11]. In 1861 Keller also noted “It is a pity that the organic material that is not charcoaled cannot be preserved in any other way than by keeping it in the water. It is well possible with little objects that can be put in water inside test tubes and sealed up by heating the glass at each end” [11].

The British Museum’s collection of lake dwelling textiles includes both darkened pieces and lighter-coloured textiles and also several examples sealed in liquid in glass tubes as described by Keller, including a very well preserved skein of plied fibre cord, Figure 2.

METHODS

Conservation condition assessment

A conservation condition assessment of the entire textile collection and its housing was carried out while evaluating the most suitable future storage for the collection. Each fragment was examined visually and the presence of any consolidants or adhesives used to secure fragments to glass or to card was recorded along with a brief description, provenance, storage method and dimensions of the fragment and frame. Evidence of movement or fragmentation of the textiles was also noted, as were any breakages of the glass and any failed or temporarily replaced adhesive tape. Discolouration of card associated with the frames was noted as a likely indication of acidity. As part of this assessment every textile was photographed, from both sides in many cases, to ensure that the current condition of the textiles, the original mounting and any labels were fully recorded.1

Textile fragments that might prove particularly suitable for further investigation were noted, those for example that: bore signs of the use of a consolidant or adhesive; had interesting weave structures; had particularly fine or complex weaves that might suggest the use of colour and so be suitable candidates for dye analysis; or had colour or textural variations that might indicate the use of two different fibre types within the same textile. Those fragments that were not enclosed in frames, and which were thus more easily accessible for further study, were highlighted.

Technological analysis: macroscopic examination and weave analysis

A selection of 45 individual pieces was examined by one of the authors (SH) with the intention of creating full curatorial catalogue records.2 These pieces were examined using hand lenses (×4 and ×10) and measured (through the glass mounts) with digital callipers. A brief description of each textile examined was recorded, followed by details on the spin direction, thread diameter, thread count per centimetre, weave structure, decoration and borders. Three textile fragments were selected for fibre identification and for these a brief description of their technological analysis is included in Table 1 and discussed below.

Scanning electron microscopy (SEM) examination and fibre identification

On the basis of the conservation condition assessment and the accessibility of the material for sampling, eight textiles, including three that were the subject of technological analysis, were selected for fibre identification. As the textiles sampled did not include any of those that are sealed (dry) between glass mounts or preserved in liquid in closed glass vials, they are not totally representative of the whole collection, but may be considered to include some of the most challenging or compromised material in terms of assessing the research potential of the collection.

Examination was undertaken in a variable pressure SEM (Hitachi S-3700N) using the backscatter detector at 15 kV with a working distance of c.18 mm. As the fibrous material of the samples was in a friable condition, with variable amounts of consolidant and detrital material adhering, the SEM chamber was only partially evacuated (40 Pa). The 3D mode (rather than Compositional) was selected to maximize the opportunity to reveal diagnostic features on the fibres and other plant cells. Samples were placed on adhesive carbon discs mounted onto stubs; no other sample preparation was required.

Chemical characterization of fibre condition and consolidants

The nature of the consolidant(s) used was investigated using Fourier transform infrared (FTIR) microscopy. Tiny subsamples from those taken for SEM examination were soaked briefly in cold de-ionized water, methanol and/or dichloromethane. The extracts were then dried prior
<table>
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<th>Sample No.; registration No.; findspot</th>
<th>Artefact type/description</th>
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<td>1; 1863.0707.47; Wangen, Lake Constance, Germany</td>
<td>Three fragments of plain weave textile; two pieces of cord</td>
<td>Plain weave fragments: all warp and weft z-spun and S-plied. One fragment has a weave of varying density. For the other two there is a thread count of 5–6 per cm in the warp (1 mm diameter) and 8 per cm in the weft (0.7–0.8 mm diameter) Cord: z-spun (anticlockwise) threads of 3.8 mm diameter plied in an S direction (clockwise)</td>
<td>Plain weave fragments: processed and unprocessed flax fibres (Linum usitatissimum) and fragments of lime/linden (Tilia sp.) bast fibres. Tiny slivers of lime sapwood and bark noted adhering to the bast fibres, probably resulting from the bark and sapwood removal process. Consolidant and detrital material</td>
<td>Plain weave fragments: FTIR shows a carbohydrate-based consolidant (colourless water extract). Raman indicates amorphous carbon associated with fibre</td>
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<td>2; OA.10859; Robenhausen, Switzerland (Figure 3a)</td>
<td>Braid in repp with fringe (4.2 × 3.4 cm)</td>
<td>The warp produces a narrow braid with weft threads extending on one side forming a fringe (up to 26 mm, although now broken and possibly originally longer) and a selvedge on the other. 20–23 warp threads over the 8 mm repp braid in contrast to c.13 per cm in the warp. Warp and weft threads (0.5–0.6 mm diameter) are evenly spun two-ply in an S direction. The warp forms bulk on one side only</td>
<td>Flax fibres in the form of fibre bundles and individual fibres. A few small fragments of lime bark were present. Consolidant visible with many modern fibres adhering to the surface</td>
<td>FTIR shows a diterpenoid resin consolidant (yellow methanol extract). Raman indicates amorphous carbon associated with fibre</td>
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<td>3; OA.10860; Robenhausen, Switzerland (Figure 3b)</td>
<td>Three pieces of fine open twining (4.6 × 4.5; 2 × 2; 0.7 × 1.3 cm)</td>
<td>Open twining with 5.5 passive elements (1.4–2 mm diameter) per cm and around two active elements (1 mm diameter) per cm, twisted 5–7 mm apart. Passive and active elements are both two-ply using two z-spun threads that are S-plyed</td>
<td>Key features of the flax fibres were visible although the diameters and dimensions of the fibres have changed due to being waterlogged and dried out. Consolidant and detrital material</td>
<td>FTIR shows a diterpenoid resin consolidant (yellow methanol extract). Raman indicates amorphous carbon associated with fibre</td>
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<td>4; 1888.1218.594; Lac du Bourget, Savoie, France</td>
<td>Basket fragments</td>
<td></td>
<td>Fragments of lime bark and sapwood, with the occasional flax fibre (possibly accidentally incorporated)</td>
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<td>5; OA.10834; Swiss lake, but no exact findspot (Figure 4)</td>
<td>Ball of string with fragments</td>
<td>Flax fibre bundles and individual flax fibres in association with many fragments of lime bark and sapwood (Figure 4b). Consolidant(s) present (Figure 4a)</td>
<td>FTIR shows a natural resin consolidant (orange dichloromethane extract). Raman indicates amorphous carbon associated with fibre</td>
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<td>6; OA.10836; Lac de Neuchâtel (?), Switzerland (Figure 5)</td>
<td>Thread wound on a wooden spindle</td>
<td>Flax fibre in the form of bundles and individual fibres. A few small fragments of lime bark were present. Consolidant and many modern fibres visible. Small chalky 'plugs' adhering to the ends of some flax fibre bundles (Figure 5)</td>
<td>FTIR shows a carbohydrate-based consolidant (colourless water extract). Raman indicates amorphous carbon associated with fibre</td>
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<td>7; OA.10838; Mörgigen, Switzerland</td>
<td>Roll of charred thread</td>
<td>Highly fragmented and brittle bundles of flax fibres and lime bast fibres as well as some slivers of Tilia sapwood. Much detrital material</td>
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<td>8; OA.10846; Robenhausen, Switzerland (Figure 6)</td>
<td>Fragment of netting(?)</td>
<td>Tangled assortment of fragmented flax and lime bast fibres with small splinters of lime sapwood. The poor condition of this material, the high proportion of detrital material and the large soil particles have resulted in many of the fibres remaining unidentifiable without further treatment (Figure 6)</td>
<td>No consolidant extracted, but FTIR spectra of fibres suggest degraded but not charred cellulosic material (match to spectra for wood cuttings/bark). Raman shows no amorphous carbon associated with fibre, but equipment not suitable for detecting carbohydrate</td>
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to FTIR analysis using a Nicolet 6700 spectrometer with a Continuum microscope. Following solvent extraction, the fibres were examined using a Raman microscope – a Dilor Infinity spectrometer with green (532 nm) and near infrared (785 nm) lasers – to explore the chemical nature of the fibre surface; the results are given in Table 1.

RESULTS OF EXAMINATION FOR SELECTED TEXTILES

Conservation condition assessment

Although the unusual burial environments of the lake dwelling excavations have led to the survival of textiles, the condition of these textiles varies greatly. While part of the collection has previously been displayed, this is not discernible from their condition.

The majority of the textiles appear brown and charred and are mounted between sheets of glass, contained in old glass and cardboard boxes or sealed in liquid-filled glass vials, Figure 2. These mounts are all believed to date from, or shortly after, excavation. Labels on the frames sometimes give the object’s accession date and findspot, while signatures, printed names, the style of handwriting or style of mounting often allow attribution to individual or original collectors, Figure 1. For those objects housed between two sheets of glass, the quality of the framing varies; sometimes the glass has been very roughly cut without ensuring that the edges were squared, Figure 1b. Many of the textiles, including fine complex weaves and netting, are at risk due to acidic mounting materials (including paper, card or cork, sometimes used as spacers for thicker fragments), broken glass or loose fragments trapped in their frames. Other textiles are stuck to the glass with adhesive, Figure 1c. A few examples have been rehoused by packing with acid-free paper in plastic boxes.

Many of the textiles examined appear to have been consolidated, presumably while still waterlogged at the time of excavation, but there are no records of these or any subsequent treatments and it is unclear to what extent the original orientation or juxtaposition of any or all of the fibres was preserved during this treatment.

Technological analysis: macroscopic examination and weave analysis

The British Museum collection includes a wide variety of textile techniques from fine spun and plied thread wound into balls or skeins, to woven fragments of cloth, netting and coarser twined fabrics. In total, 45 individual pieces were examined and are fully described in the British Museum Collection Database, but for the purposes of this contribution, only the three also selected for fibre identification are included in Table 1 and discussed below (1863,0707.47 from Wangen, Lake Constance and OA.10859 and OA.10860 from Robenhausen: samples 1–3 in Table 1).

SEM examination and fibre identification

SEM examination was undertaken to assess the condition of the material and to evaluate whether the presence of consolidants would hinder present or future scientific or technological analysis. The samples examined included textiles, threads, netting and cord, see Figures 4–6 and Table 1 for details. All the samples examined were dark brown or black in colour, rather glossy in appearance and visual inspection suggested that they might be charred. However, none of the cellular features showed any of the characteristic alterations that take place as a result of charring or burning, suggesting that any singeing was superficial or occurred at temperatures less than 360°C, above which cells show distinctive changes as they begin to convert to charcoal.

In all cases, the presence of consolidants, modern fibres, detrital soil particles and other materials masked some of
the key features required for swift identification of the fibres, but sufficient features could be discerned through detailed examination. Processed and unprocessed flax fibres (*Linum usitatissimum*) and fragments of lime/linden (*Tilia* sp.) bast fibres were identified. By comparison with reference specimens, it is clear that the diameters and dimensions of the flax fibres have changed in many of the samples due to being waterlogged then dried out, with or without consolidation.

**Chemical characterization of fibre condition and consolidants**

All the samples were very hard and brittle with, in several cases, large quantities of consolidant adhering to and between the fibres. This could be seen under low magnification, while SEM examination further confirmed the presence of consolidants in the majority of samples examined, Figures 4a and 5a. Solvent extraction combined with FTIR spectroscopy allowed the range of consolidants to be characterized. In two of the samples examined (Nos 1 and 6 in Table 1) the consolidant was highly water soluble and is some form of carbohydrate-based material present in very high proportion in the sample. A natural diterpenoid resin, soluble in methanol, was present in the example of twining (No. 3), while a different natural resin, soluble in dichloromethane, has been used to consolidate the ball of string (No. 5). Under the conditions used, no consolidant was extracted from netting fragment No. 8 and this sample appeared less black and glossy than the other samples examined.

After solvent extraction each of the fibres was examined using FTIR and Raman spectroscopy to determine the chemical condition of its surface. Of particular interest was whether the dark colour of the textiles was linked to charring or processes occurring during the air drying of biodegraded textiles [4, 12, 13]. Although the Raman spectrometer used was not suitable for determining if carbohydrate is present,
for those fibres where a consolidant had been present, the Raman spectra clearly indicated the presence of amorphous carbon and no bands typical of cellulose could be seen in the FTIR spectra, see below. The single exception was the netting fragment No. 8, which did not seem to have been consolidated, Figure 6. Here the fibres did not appear charred but gave FTIR spectra consistent with a degraded cellulose-based material.

Sample No. 6 was re-examined in the SEM after removal of the gum consolidant. Prior to this treatment, many of the individual flax fibres had been located in a ‘sheet’ of consolidant that was cracking in many places, Figure 5a. After removal of much of this consolidant, the diagnostic features of the flax fibres were more distinctly revealed, although some detrital material and residual consolidant were still present, Figure 5b. Consolidant removal improved the potential for fibre identification but inevitably disrupted the orientation and juxtaposition of individual fibres or fibre bundles.

**DISCUSSION**

*Potential for technological and scientific examination*

The first substantial study of the lake dwelling textiles was carried out by Emil Vogt [14]. In his monograph, which remains largely relevant today, basketry, twining and nets (*Die Geflechte*) were considered as distinct from weaving (*Die Gewebe*), and classifications were established for different methods of interlacing, e.g. separating knotless and knotted netting [14; pp. 33–37]. Further progress in textile research and technological analysis came in the late 1980s and 1990s with the definition of criteria for the documentation of archaeological textiles [15], the use of microscopic fibres analysis [16], and SEM examination [17]. Experimental reconstruction or replication work is providing further knowledge about the processing and production of...
fibres, threads and materials. These studies have shown that, as for the British Museum objects examined here, flax and lime bast fibres were used widely throughout the lake dwellings for textiles and basketry [1, 9, 11, 18, 19; pp. 73 and 107]. The use of bast fibres from oak, elm and willow, as well as Viburnum, grasses and reeds, has also been suggested [16; pp. 135–143, 17; p. 48, 20; p. 49, 21, 22].

The technological analysis of textiles following these standards is now an integral aspect of lake dwelling excavation reports and using this model it was possible to make basic technological classifications for all 45 pieces examined from the British Museum collection, even those mounted between glass. Three objects from this group from Wangen, Lake Constance and Robenhausen are described here to represent a range of weaving and other techniques, Nos 1–3 in Table 1. Despite the presence of consolidants and other detrital material, and changes in fibre dimensions linked to air drying, fibre identification was also possible using SEM for these and other readily accessible objects, Table 1.

The cord from sample No. 1 can be compared to other fragments from Wangen held in different collections [16]. Fragments of lime/linden (Tilia sp.) bast fibres with tiny adhered slivers of lime sapwood and bark were noted in addition to processed and unprocessed flax fibres (Linum usitatissimum). Comparison with lime bast fibres produced as part of an experiment by one of the authors (SH), suggest that the tiny adhered slivers result from the process of removing the bark and sapwood. Bast fibres come from the inner bark of the tree, between the bark and the sapwood. To obtain the bast fibres, the bark first needs to be removed from the tree. This can be from a living tree or from felled branches, in each case by cutting across the bark and pulling it away from the sapwood, Figure 7. Both outer and inner bark will be removed and these need to be processed further to separate the inner bark (bast fibres) from the outer bark. Variations in these processes have been recorded [16; p. 139, 20; p. 49 and Figure 15, 23; p. 82, 24; pp. 27–36]. In this experiment, lime bark was removed from felled branches in summer and processed by water retting for a period of six weeks. After retting, the bast fibres from the inner bark were loose and could be peeled away in layers from the outer bark [25; pp. 63–65 and 84–85]. From SEM study of the experimentally produced lime bast fibres it was possible to observe the same presence of adhered sapwood and bark slivers as in sample No. 1.

Repp is a weaving technique in which one set of threads is denser than the other. This creates a visible effect as one set of threads will partially or completely cover the other set of threads. If the warp is denser than the weft it may be called a warp-faced repp and vice versa. Determining whether a textile is warp- or weft-faced depends on the presence of technical features preserved in the archaeological sample. Sample No. 2 is a narrow braid in repp. In this case it is most likely warp-faced as the other set of threads, the weft, extend beyond the narrow braid forming a fringe to one side and a selvedge on the other. Repp weaving can also be achieved by using threads of different thicknesses, although this is not the case here. A similar piece, ‘Gewebe 7’, was published by Vogt [14; pp. 61–62 and Figures 97–99]. In sample No. 2 one end of the repp section is markedly straight and this contrasts to the broken-off fringe and irregular appearance of the other end. Textiles from these early excavations were known to have been cut into smaller pieces for sale (see above), and the straight edge may reflect this practice. As the similarity to Vogt’s Gewebe 7 is very striking, it is not impossible that these were originally part of the same piece, cut up for sale in the nineteenth century.

Twining is one of the most common cloth features found in the Neolithic lake dwellings and may also be one of the earliest construction types in Europe, although evidence before the late Neolithic is very scarce [1; pp. 117–118]. It is found on many different scales, from fine threads such as
suggesting that the flax was retted (to some extent) to some extent, has allowed the authors to reconstruct the process from the canton of Zurich and on experimental reconstruc-

Leuzinger and Rast-Eicher, using SEM on Neolithic textiles sample No. 3 appear to be spun into simple yarns (z-spun), assessment with a hand lens, the fibres for the objects in process of retting, combing and spinning; on the basis of objects in the Swiss lake dwelling textiles has been prompted by a number of textiles from Robenhausen and Irgenhausen, including the so-called Irgenhausen 'brocade' linen (presumably the fragments described by Keller as "embroideries" [2; pp. 58–59, 330 and Plate XCIV]), which is frequently cited as a particularly striking example of a patterned textile with a highly complex weaving technique. This unique piece has been repeatedly and erroneously published as an example of a Neolithic patterned textile [14; pp. 76–90, 33; p. 139]. However, a radiocarbon date of 1685–1493 cal. BC, dating it to the middle Bronze Age has subsequently been obtained [34]. The British Museum has a fragment (1910,0707.133) thought to belong to the same piece, but as it is mounted between sheets of glass it was not sampled as part of this study. Although no evidence of colour remains, the textiles have such elaborate patterns that the original use of coloured threads has been argued [14, 33, 35]. The decoration may, however, simply have been textural with different thread types or spinning techniques used to produce variations [36]. No recent dye analysis on lake dwelling textiles has been conducted [36, 37], although the prehistorian Walter von Stokar is claimed to have detected red, blue, purple and yellow on Neolithic textiles, the colours having "been made visible after nitric acid and diluted caustic potash treatments" [33; p. 224, 38; p. 12].

In this context it was therefore important to establish the chemical condition of the fibres to determine whether dye analysis might be feasible. Using the SEM it was possible to show that, despite their blackened visual appearance, none of the fibres examined demonstrated any of the char-

characteristic alterations or behaviour that occurs as a result of charring or burning at temperatures over 360°C. As discussed below, the presence of consolidants was also confirmed. The possibility that the dark colour of some of the textiles was a result of the consolidation process [39], the burial environment or processes occurring during the air drying of biodegraded textiles [4, 12, 13], was therefore considered. However, the spectroscopic results for four of the samples (after extraction of any consolidant) indicated that there was no remaining molecular cellulose and instead only amorphous carbon was present at the surface of the fibres. This new evidence strongly supports Keller’s suggestion that the survival of some of the textile specimens is due “… to the fact, that at the time the huts were destroyed, they fell burning into the water before they were entirely reduced to ashes and were very soon after covered
over by the mud of the lake" [2; p. 323]. Such fibres have thus survived through a combination of a brief, fairly low temperature or incomplete charring and then rapid transfer to an anoxic environment.

Given that the majority of the samples examined during this pilot study showed signs of this rapid, incomplete charring, the potential for organic dyes analysis seems poor, although only textiles that were uncharred and immediately accessible for sampling were included in this study. These were not representative of the entire collection and did not include the finest textiles, thus adding to the dilemma of whether to make additional textiles (particularly uncharred textiles) that seem stable from a conservation point of view accessible for analysis. For example, some of the best preserved specimens are those currently in liquid-filled sealed glass vials.

The textiles within the British Museum’s collection of Swiss lake dwelling material were excavated and treated using nineteenth-century approaches that would no longer be considered appropriate and have lost much of the evidence of their original stratigraphic and spatial context. The presence of consolidants and other detrital materials makes fibre identification challenging and, particularly for the fibres showing evidence of low temperature or incomplete charring, suggests that (bio)molecular analysis may be compromised. While radiometric dating is likely to be possible and may indeed be helpful for poorly provenanced pieces, the problems of interpreting data from single measurements and without a proper archaeological context remain. However, although some areas of research have been compromised by the circumstances of excavation and early preservation, and there is limited access to some of the textiles, this pilot study has revealed that the collection still retains great potential for technological and scientific research. It has also provided a valuable insight into the condition of the collection and emphasized the importance of museum collections that may retain rare examples of textiles not represented in finds from current lake dwelling excavations. Further, while recently discovered sites offer much potential for studying textiles and associated artefacts that have been recorded in their stratigraphic and spatial context, supported by absolute dating and conserved with the benefit of modern techniques [16, 40–42], in several instances new areas of old sites have been excavated, thus allowing the earlier finds, including textiles and basketry, to be considered alongside the new finds; this is the case at, for example, both Robenhausen [20] and Port Stüdeli [43].

The British Museum material in the context of the development of archaeological textile conservation

The majority of the samples examined, and all the samples that showed evidence of low temperature charring, were shown to have undergone (early) consolidation and/or past conservation. It is possible that other consolidants may also have been used but were not extracted under the conditions applied here, but no obvious correlation between the choice of consolidant and object type is apparent. It is also unclear when the pieces examined were consolidated: consolidation may have been a standard procedure for all the excavated textiles, or these objects may always have been more accessible and vulnerable and may, therefore, have required (or have been amenable) to treatment. Since none of the framed British Museum textiles has been opened to allow detailed examination, it is unclear whether these textiles have also been consolidated or simply air dried.

Data collated by Travis and others suggest that, until the advent of the use of modern synthetic polymers or freeze-drying methods, waterlogged textiles were normally treated with substances such as alum, wax, resins or balsams, oil-based substances, glycerine or animal glues [11]. The use of carbohydrate-based consolidants (possibly gum, sugar solution or similar) is not reported by Travis in the context of lake dwelling material and it is tempting to suppose that the absence of synthetic materials might suggest early treatment, but without treatment records no firm conclusions can be drawn. Starch pastes and plant gums have a very long history in conservation treatments and the use of sucrose or related materials specifically for consolidation of waterlogged archaeological wood is referred to in the very late nineteenth and early twentieth century, but the application could be much more recent: sucrose as a consolidant has been the subject of increasing interest since the 1980s [44, 45], and Travis also notes the experimental use of Noredux A 100® (potato starch) on lake dwelling textiles by the Swiss National Museum in the 1970s [11].

Recognizing the use of such consolidants is important for any future conservation treatments as textiles may be very water- or solvent-sensitive, although the easy removal of the consolidant from subsamples may aid aspects of future scientific or technological examination.

These past treatments and the practice of placing the textiles between glass sheets have both positive and negative
impacts on the possibility of examining weave structure. On the positive side, they have helped preserve some of the textiles for over 100 years since their excavation; the preservation of textile finds from early excavations is patchy, so their very survival is an important benefit. Secured flat and placed in the middle of a glass sheet eradicates the problem of folds or hidden areas that may be encountered if they were crumpled in storage. In this position the weave structure is visible both front and back and measurements can be taken, although these are compromised by the glass. Conversely, information on the original shape at recovery (folded, layered, crumpled) and hence any evidence of original use or function may be lost, measurements are hampered because they have to be taken through the thickness of the glass and it is not possible to collect samples for microscopical identification. The problem is more acute for textile fragments sealed in glass boxes. Those packed in plastic boxes that can be opened are more accessible but tend to be more vulnerable to movement, crushing during handling and contamination.

Rehousing the collection and future conservation approaches

Many of the textiles included in this pilot study appear stable from a conservation perspective, but options for how best to treat those in need of further conservation are being investigated. About a quarter of the textiles was found to be in need of conservation due to broken glass, acidic mounting materials or the fragmentation of the textiles leaving them at risk of movement within the frame. The mounting of textiles between two glass sheets to allow both sides to be seen encourages turning over of the glass enclosure, which can be an additional source of damage.

The immediate priority has been to rehouse the textile fragments (while retaining their existing mounts) to make them safer to access and study and for future storage. To avoid the handling and potential for damage associated with the unwrapping and wrapping of tissue-covered mounted textiles, a cost-effective, standardized storage system was adopted. Clear, inert, stackable A4 polystyrene boxes, available in a variety of depths were chosen, through which the contents could easily be identified [46]. The fragments in glass frames, vials and more three-dimensional examples were cushioned within the boxes in polyethylene Plastazote® foam and acid-free tissue paper, while leaving the textiles visible through the clear lids, Figure 8.

For those textiles still at risk in their historic mounts, a range of treatment methods will be required as the textiles vary greatly, including two- and three-dimensional examples, and present different challenges. To determine whether it will be possible to remove a textile from its mount without damage, work may be needed to identify the old consolidant(s) and any adhesives or past conservation materials. Where possible, the existing original mounts will be retained as a part of the object, by conserving and repairing as necessary, before considering new methods of remounting. These mounts are intrinsic to the history of these textiles, and the preservation of the mounts must be balanced against the need to ensure the safety of the textiles or the desire to access the textiles for analysis to increase knowledge and understanding of the material. If it is decided to remount any textiles from the ‘at risk’ category in the future, the possibility of continuing to make both sides of the textile accessible will be a significant consideration. In addition to conserving those textiles at risk, it is hoped to make a selection suitable for future display and so to increase the representation of archaeological textiles in the British Museum and raise awareness of the Museum’s holdings of such material.

CONCLUSIONS

Conservation techniques and ethics have advanced greatly since the textiles that form part of the British Museum’s collection of Swiss lake dwelling material were excavated and first conserved and mounted in the nineteenth century, but these rare textile survivals from early excavations are highly significant. A combined conservation assessment and rehousing project to improve the future safety of the entire collection has recently been undertaken. The assessment highlighted the importance of retaining original historical mounts as integral parts of the objects to ensure that the information they may hold is not lost and as a record of social history. This pilot study of the more accessible textiles, and the wider technological and cataloguing study undertaken by one of the authors (SH), has demonstrated the research potential of this historic collection and shown that although some areas of technological and scientific research have been compromised by the early treatment, it is still possible to extract valuable information.

This study has confirmed the value of weave analysis and allowed technological classification, even for textiles still in their original mounts. On the basis of the examination of a subset of accessible textiles, which may not be entirely representative of the whole collection but that represents some of the least promising material for research purposes, fibre identification has been shown to be possible, if challenging, even with the presence of consolidants, detrital material and dimensional changes to fibres due to air drying. The success of the SEM study was greatly enhanced by the availability of experimentally produced and processed fibres. Raman and FTIR spectroscopy have been shown to be a valuable combination in determining the chemical condition of the textiles and have been used, with SEM examination, to confirm low temperature or incomplete charring of many of the textiles examined, as suggested by Keller. The state of preservation of the uncharred textiles is more variable. All of the charred samples examined showed evidence of consolidant treatment and a range of (apparently early) consolidants was identified by FTIR.
The combination of past treatment, contamination and low temperature charring suggests two slightly conflicting possibilities. Due to contamination, some types of (bio) molecular analysis, including dye or DNA analysis, may not be fruitful or would be compromised, at least for some of the textiles in the collection. However, in theory, the presence of fibres that are not carbonized, or are only partially carbonized, could permit (bio)molecular preservation and present analytical opportunities. Other information has also been lost or compromised, such as the original shape at recovery, and much of the collection lacks clear contextual evidence. While radiometric dating may be both possible and potentially helpful [21: Catalogue Nos 39 and 41], interpretation of the results may be more problematic. Nevertheless, material from historic collections can usefully be considered alongside new finds from more recent excavations or may include rare or potentially diagnostic fragments.

Many of the Swiss lake dwelling textiles in the British Museum collections, including fine, complex weaves and netting, are now at risk due to their nineteenth-century collectors’ mounts being insecure, fractured or constructed using what might now be considered inappropriate materials. This study has, however, highlighted the importance of preserving, re-examining and documenting historic collections as records of nineteenth-century approaches to archaeology and collecting and of the development of archaeological conservation. This contribution aims to raise awareness of both the research potential and the historical information preserved in often overlooked historical collections of archaeological materials and information from this study and other curatorial research on the Swiss lake dwelling materials is being made available via the British Museum Collection Database. The results of this pilot study will guide the future conservation strategy for this collection and allow informed decisions to be made regarding future access for technical and scientific study.

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NOTES

1. Details of the textiles discussed here can be found on the British Museum Collection Database online, www.britishmuseum.org/research/search_the_collection_database.aspx (accessed 11 July 2011).

2. The British Museum registration numbers of those pieces that have full curatorial catalogue records are: OA.10844; OA.10845; OA.10847–OA.10851; OA.10855–OA.10860; 1863,0707.47; 1863,0707.51; 1863,0707.55; 1863,0707.56; 1863,0707.57; 1863,0707.94; 1910,0707.125–1910,0707.128; 1910,0707.130–1910,0707.134; 1910,0707.136; 1916,0605.166; 1935,1008.0070; and 1964,1206.0741–1964,1206.0747. It should be noted that several of these numbers represent multiple fragments.