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Textiles in a Viking Age hoard: Identifying ephemeral traces of textiles in metal corrosion products

Mary Davis [a,*], Susanna Harris [b]

[a] National Museum Collection Centre, 242 Granton Road, Edinburgh EH5 1JA, United Kingdom
[b] School of Humanities, University of Glasgow, 1 University Gardens, Glasgow G12 8QQ, United Kingdom

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ABSTRACT

This paper presents a novel method and terminology to identify and describe textiles from ephemeral traces in metal corrosion products. Since the 1980s, mineralised textiles (positive and negative casts in Janaway's terminology) have been an important source of archaeological evidence. A major issue now is the identification of textiles in metal corrosion products when only faint traces remain. These traces no longer appear like textiles and are vulnerable to misinterpretation. Confused with metal dendritic structures or the form of corrosion products themselves, they are often lost through handling or cleaned off through conservation practices. This loss is cumulatively significant. To remedy this issue, this paper defines and characterises the form and structure of ephemeral traces of archaeological textiles through examination of metal corrosion products on a Viking Age hoard from Scotland. It defines a new terminology to supplement Janaway: petal shapes, remnant textile surface, ghost textile surface. The analysis follows an investigative inquiry from assessment to laboratory analysis using a Dinolite portable digital microscope, optical light microscopy with Z stacking and scanning electron microscopy (SEM). The results allow the secure identification of textiles from previously unidentified corrosion features. The method has wide applicability to corroded archaeological metal objects and has the potential to significantly increase the identification of textiles associated with metals and transform current understanding of hoards.

1. 1. Textiles in metal corrosion products

Metal corrosion products on archaeological artefacts preserve a wide range of organic materials, including textiles (Peška et al. 2006). While several terms are used for the resulting textile structures (mineral preserved, pseudomorph, mineral replaced, fossilised), this paper follows Chen et al. (1998) and describes the textile as mineralised, a broad term whereby the physical shape of the textile fibre is replaced by minerals (Chen et al 1998, 1016). Research into the process of textile mineralisation has been carried out over several decades (Janaway, 1983; Janaway, 1985; Janaway, 1989, Gillard et al. 1994; Chen et al. 1996; Chen et al. 1998; Peška et al. 2006; Grömer and Grassberger 2018). A general theory about the progression and outcomes of these processes has developed, including understanding the mineralisation process (Gillard et al. 1994; Chen et al. 1998; Reynaud et al. 2020). For textile archaeologists, the research into mineralised textiles has had two main outcomes. These are the characterisation of the textile fibre from positive and negative casts or chemical analysis (Janaway, 1983; Rast-Eicher, 2016; Margariti, 2019; Anheuser and Roumeliotou 2003), and the identification of weave structures through microscopic analysis, often with the assistance of scanning electron microscopy (e.g., Bender Jørgensen, 1992), or a combination of both (Bender Jørgensen, 1992; Rast-Eicher, 2008; Gleba, 2017). This research has laid the foundation for the analysis of mineralised textiles that can be readily identified because they retain the appearance of textiles.

As the field has progressed, a developing challenge has been to securely identify textiles from more obscure traces and preservation of partial or possible textile features in metal corrosion products (e.g., Angiorama et al. 2020; Caricola et al. 2022). The identification of such characteristics is less certain and can lead to textile features in corrosion products being misidentified, remaining unidentified, or not ascribed as textiles due to methodological and identification uncertainties. This hesitancy is significant because it leaves traces of textiles unidentified in contexts where their presence substantially changes the interpretation of the artefacts in question. To address this challenge, this paper identifies ephemeral traces of textiles in metal corrosion products and introduces terminology and method to describe and characterise their form and structure. The evidential basis is achieved through the analysis of

* Corresponding author.
E-mail address: m.davis@nms.ac.uk (M. Davis).

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Table 1
Four categories of mineralised textiles recognised by Robert Janaway.

Category of mineralisation	Preservation	Associated materials
1.Textiles preserved by metal ions, appear as organic	Metal ions serve as a biocide limiting biological decay	Mostly associated with copper alloys
2.Textiles preserved by metal corrosion products forming a negative cast	Corrosion products cover the fibres forming a tubular mould	Mostly associated with iron
3.Textiles replaced by metal corrosion products forming a positive cast– textiles may or may not be preserved.	Positive replica of the fibre is formed by infiltration of corrosion products	Associated with iron and copper alloys
4.Combined negative cast and metal replaced textiles	As above in combination	Mostly associated with iron

Fig. 1. Map showing the location of the Galloway Hoard, found in south-west Scotland.

ephemeral traces of textiles in the exceptional and varied metal corrosion products of the Galloway Hoard, an early medieval (c. 900 CE) deposit from Kirkcudbrightshire, Scotland.

The application of this method and characterisation, securely establishes the presence of textiles in the metal corrosion products. The results raise questions as to the nature of the hoard itself which appears to contain wrapped and bundled heirloom or relic objects. Although wrapping amuletic or relic material is referred to in early medieval texts (e.g., Bede), extant examples from this period mostly come from ecclesiastical contexts on the continent (Smith, 2012, 2014); this is a unique archaeological find in such circumstances. As a result of identifying textiles from ephemeral traces in metal corrosion products, this method has transformed the understanding of the contents and deposition of this early medieval hoard. It also provides a tested method applicable to other hoards.

1.1. The process of mineralisation

The breakdown of organic materials such as textiles usually occurs rapidly within the burial environment due to decay by microorganisms (Janaway, 1985, 30); however, the presence of metals, especially iron and/or copper can promote the preservation of organic materials (Janaway, 1983, 48; 1985, 30). Organic acids, as the by-products of the breakdown of the fibres by microbial decay, produce an acidic environment within the region of the organic materials, this in turn promotes the oxidation of adjacent metals: in this case study, copper within the silver alloy. The copper forms copper (II) ions within this environment, which can dissolve and become mobile (Chen et al. 1998, 1016). As microbial degradation can occur both in the amorphous and crystalline regions of fibres, copper ions in solution can either accumulate to form encrustations on the surface of the fibres (sometimes forming a negative cast within this outer layer), but also penetrate into the fibre. This means that copper ions can also gather inside the fibre structures to form complexes with cellulose molecules, which later might transform into cuprous or cupric ions either inside or outside the fibre structure (Chen et al. 1998). The toxicity of the copper ions in direct contact with microorganisms associated with the decay of organic materials such as cellulose fibres can prevent complete degradation of the fibre constituents, thereby allowing mineralised fibres to be preserved or partially preserved. Over time this can result in the formation of textiles fully composed of mineralised copper.

Variations in the biological breakdown of fibres and the biocidal properties of copper also affect the form in which the information about the mineralised textiles is retained. These are often described as either negative or positive casts (Janaway, 1983 48) (Table 1, Fig. 18). Negative casts result from corrosion covering the surface of the fibres in a crust only, thereby forming a negative cast on the inner surface of this corrosion crust. Positive casts occur when minerals form within the fibre remains and preserve the form of the textile – which often have a corroded surface (Gillard et al. 1994 133), – but total replacement of the organic components is rare (Gillard et al. 1994 138). All the parameters that combine to result in the mineralisation of textiles must interplay in specific ways for their formation and survival, and the conditions necessary for the retention of positive casts is a further balancing act: 'In the case of positive casting the copper ion concentration must be high enough for biocidal action, yet sufficiently low to allow the ions to penetrate the fibre. If the concentration is too high the solubility product of the copper minerals is exceeded before the metal ions can penetrate the fibre, resulting in deposition on the fibre surface and thus the formation of a negative cast of the fibre' (Gillard et al. 1994 39). The above categories of mineralisation can, and usually do, co-occur on the surface of metal objects with mineralised textiles. This is central to the method of investigating mineralised textiles, as the same textile may be preserved in a number of physical forms, and be visually dissimilar.

2. Materials and method

2.1. The Galloway hoard

2.1.1. Deposit and content of the vessel

The Galloway hoard was discovered by metal-detectorists in 2014 on what is now Church of Scotland land at Balmaghie, near Kirkcudbright in Dumfries and Galloway (Nicholson, 2014). It was buried around 900 CE and contained a variety of items from diverse cultural backgrounds; these included Viking, Hiberno-Norse and Anglo-Saxon artefacts plus some material originating from continental Europe and Asia (Goldberg and Davis 2021). The silver arm rings and ingots within the Galloway Hoard are typical of Viking Age hoards discovered in regions bordering the Irish Sea in Britain and Ireland (e.g. Graham-Campbell, 2011), however, this hoard also contains a large number of Anglo-Saxon (Webster and Blackhouse 1991), as well as exotic objects. The hoard is highly unusual for the quantity of preserved textiles.

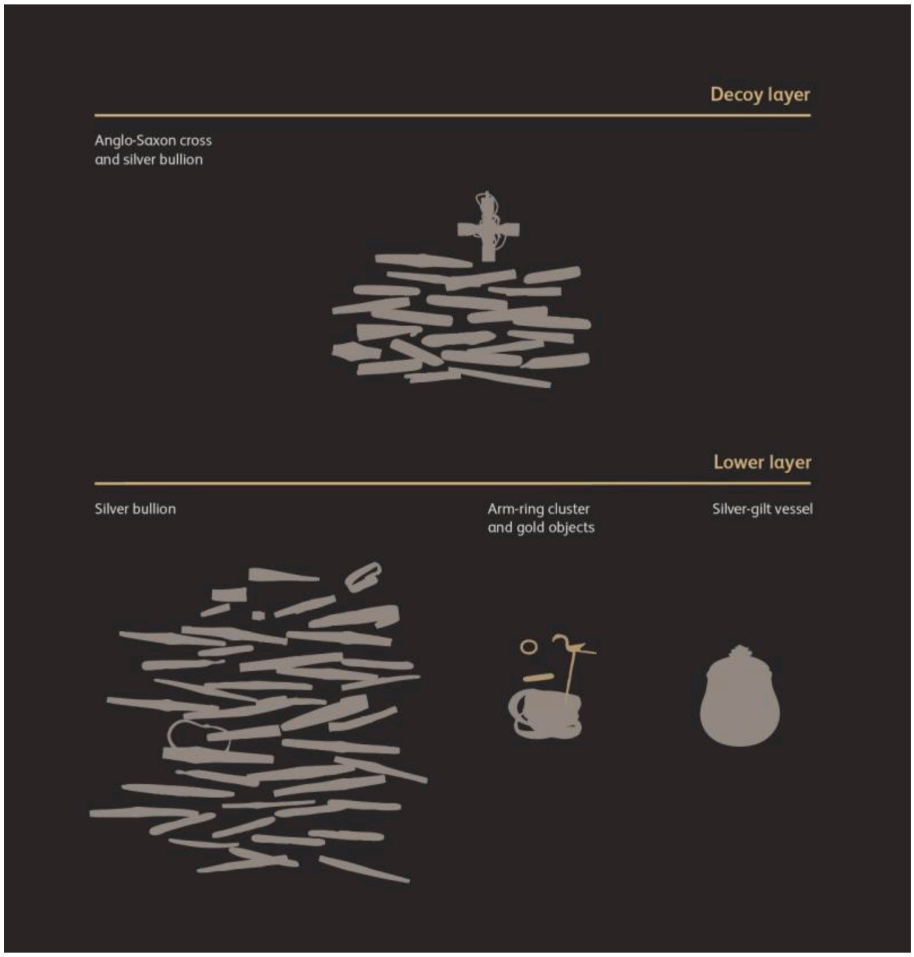


Fig. 2. Diagram showing the contents of the two layers (diagram: Kimberley Baxter).

Fig. 3. a. Image of the textiles preserved on the outer surface of the vessel (photograph: Historic Environment Scotland). Fig. 3b: Schematic image of the objects found within the lidded vessel (diagram: Kimberly Baxter).

Fig. 4. a. The vessel and its contents when first opened by the finders; ephemeral vestiges of textile impressions are visible on several objects including the glass melon bead (71.2, lower left; Fig. 5). Fig. 4b: The right-hand photograph shows the underlying penannular brooch hoop (71.9; Fig. 14) which supported many of the objects on the upper layer (Photographs Martin McSweeny).

Fig. 5. The collection of curios and beads after conservation displayed here in roughly their original locations when found resting on the Viking penannular brooch hoop (71.9) (Image © National Museums Scotland).

The hoard was buried in two layers; an initial 'decoy' layer consisted of silver bullion (arm rings and ingots), and a damaged pectoral cross (Goldberg and Davis, 2021). These objects were buried above a lower layer with more Viking style bullion, but also containing several gold items and a vessel full of a broad range of small objects (Fig. 2). It is the contents from the vessel which is the focus of this paper.

The vessel was wrapped in textiles, made of both cellulosic (plant origin) and proteinaceous (animal origin) fibres, which were examined during the conservation process. A darker more degraded layer of wool textile overlies a pale bast fibre textile partially mineralised by copper corrosion products. There was some exceptional preservation within the vessel; this container was buried with its lid in place which helped the formation of a stable environment within, preventing the percolation of water through the objects and limiting the air flow. This microclimate

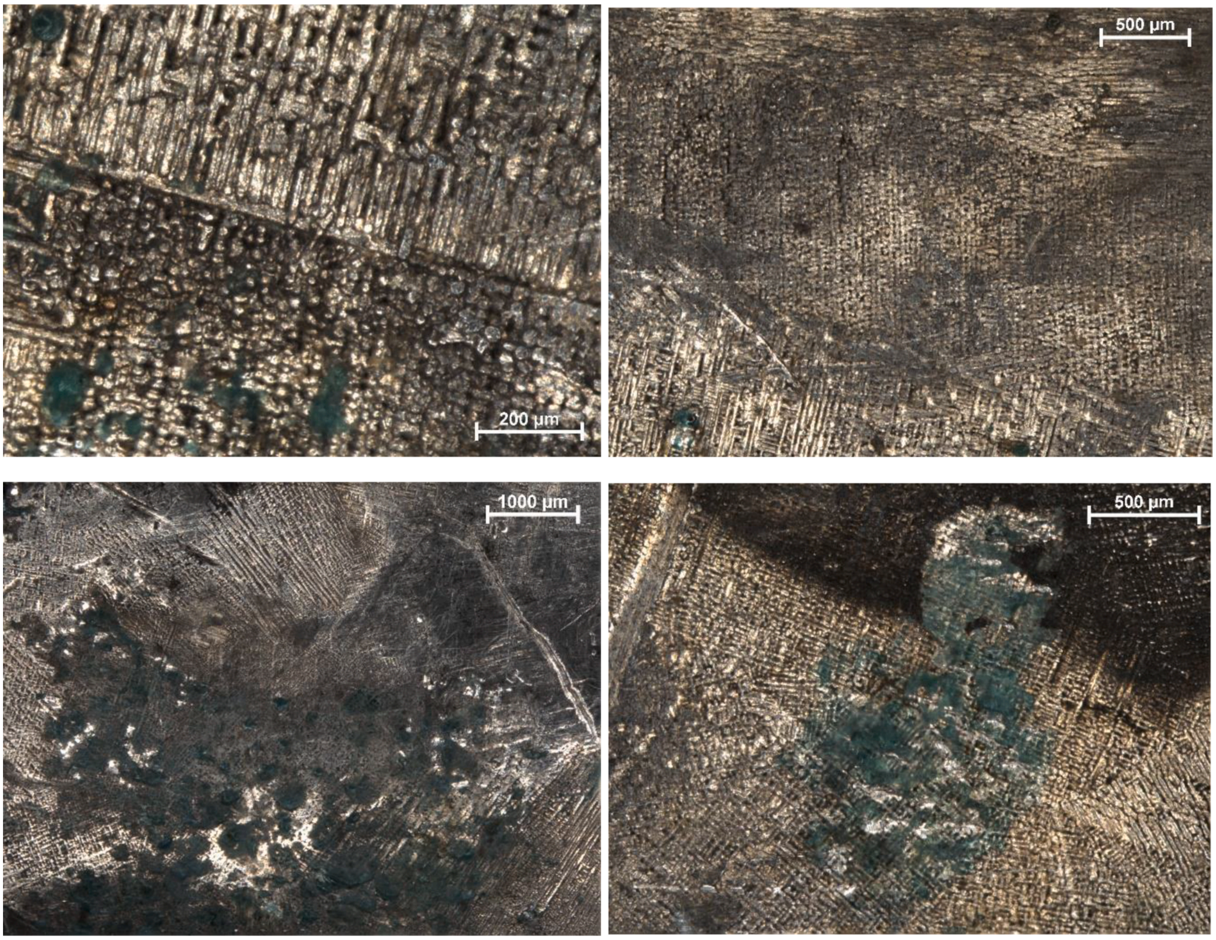


Fig. 6. Dendritic structures on silver objects from the Galloway Hoard (Image © National Museums Scotland).

had allowed the preservation of organic material which would not usually survive – including bast fibre textiles, fine leather and complex silk; the majority of these were found towards the bottom of the container. Most were preserved as organic 'bundles' enclosing gold objects, silk braids and a crystal and gold jar (Goldberg and Davis 2021, 105, 118).

There was a distinct 'top layer' of objects packed within the vessel, divided from the contents below by a horizontally placed Viking style bossed penannular brooch hoop (71.9, Fig. 5). This consisted of five glass beads (71.2; 71.3; 71.6; 71.7; 71.8), a composite bead and coin mounted with a silver pendant hoop (71.5), a rock crystal sphere bound in a silver fitting (71.4) and a hollow mineral sphere containing a loose fragment of stone, known as a rattle stone (71.1) (Goldberg and Davis 2021, 79). It could be seen that textiles had partially survived on the silver fittings of some items; however, original photographs and subsequent evidence indicate that all these objects at the top of the vessel might once have been wrapped in textiles, much of which disintegrated shortly after discovery. The relatively undisturbed contents below the penannular brooch hoop included a collection of Anglo-Saxon brooches (Goldberg and Davis 2021; 88-89, Fig. 4), and two textile bundles (Goldberg and Davis 2021, 77–83).

2.1.2. *Textile mineralisation in the Galloway vessel*

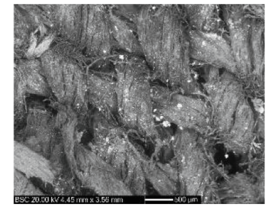
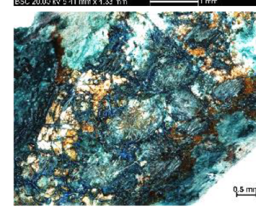
Conditions within the vessel from the Galloway Hoard helped preserve the fragile organic components. Most of the metal objects in the vessel were predominantly silver; several brooches included copper alloy components such as backplates, pins and hinge mechanisms. However, as with much modern silver, the silver objects were alloyed with varying levels of additional copper. Although the copper only made up a small percentage of the alloy, it was still significant in terms of corrosion mechanisms affecting preservation. Textiles were differentially preserved within the vessel; with better preserved textiles found closer to sources of copper ions.

It was apparent within the vessel that copper corrosion products nearly always appeared on the surface of the silver objects where they had been in direct contact with textiles or leather. The decay of these organic materials promoted the preferential corrosion of copper within the 'silver' objects. The conditions within this vessel, with limited air flow and water, allowed for the preservation of both cellulosic material in the form of bast fibres and proteinaceous fibres such as silk and leather, which is unusual within the same context (Janaway, 1989 21). It appears that textiles near sources of copper alloy components had the most chance of organic or mineral preservation as positive or negative casts. Those areas with less available copper ions, or where a mineralised textile had been physically dislodged from a surface, resulted in more ephemeral textile traces. Further research is necessary to correlate the multiple chemical and physical factors that led to the different levels of mineralisation. It was the presence of limited quantities of copper within the Galloway Hoard vessel that were most significant for preservation.

2.2. *Method*

The preservation and identification of residues and traces of textiles in metal corrosion products post-excavation depends on the retention of corroded surfaces. The maintenance of these surfaces may be contrary to the usual treatment of 'valuable' metal finds in museums, to have newly achieved shiny surfaces (Peška et al. 2006, 6). For this reason, the

Table 2
Aspects of textile structure preserved in metal corrosion products, terminology, definition and effect on textile analysis. Terminology presented here describes ephemeral traces of textiles, except for organic or mineralised textiles in positive and negative casts which were defined by Janaway (1983, 1985, 1989).

Terminology	Definition	Form and features	Textile analysis	Illustrative example
1. Organic or mineralised textile (positive or negative cast)	Textile structure fully preserved	Full textile structure: one surface of textile structure visible	Thread structure and twist visible, thread diameter and count possible.	
2. Petal shape	Characteristic form of textile binding points preserved in metal corrosion products	Roughly oval shaped traces occurring in regular, offset rows	Morphological description of traces of either remnant or ghost textile surfaces	
3. Remnant textile surface	Petal shaped traces with less than 25 % depth of textile preserved	Raised binding points of one partial surface of textile structure visible. Appearance of regularly spaced offset rows of petal shapes with features of yarn twist and fibre	Thread structure visible, twist reversed, thread diameter and count may be possible; textile structure identified to extent allowable with one preserved face, or by comparison to better preserved areas of textile	
4. Ghost textile surface	Scars where metal corrosion products of textile formed but were later detached	Regularly spaced offset rows of petal shapes with smooth, indented appearance	Minimum thread diameter, thread count if sufficient binding points are preserved, textile structure may be identified to extent allowable with one preserved face or by comparison with better preserved areas of textile	

retention and ability to study textiles in metal corrosion products depends on human action from excavation to conservation and research. An inspection of the corrosion products must be made before handling or treatment is carried out (Peška et al. 2006, 6-7). Metal corrosion products from the Galloway Hoard were examined by the conservator and textile specialist in 2018 after the objects were received by National Museums Scotland, following post-excavation conservation carried out by AOC archaeology, commissioned by Historic Environment Scotland in 2014 as part of the Treasure Trove legislative process (Treasure Trove, 2016).

The metal corrosion products on the surfaces of the objects were first assessed in 2018 using a portable laboratory with Dinolite Edge digital microscope (Dinolite Edge AM 4115ZTL) at × 20 to × 100 magnification with adjustable polariser and ring light cap. The selected areas were examined in 2019 in a scientific laboratory with a Nikon SMZ 18 optical microscope at magnifications of × 3.5 to × 135; images were captured using Z-stack adjusted photographs to gain depth of field. For examination with the SEM (CamScan MX2500), artefacts were placed uncoated in the vacuum chamber at low pressure, a backscatter detector was used with a 20 kV accelerating voltage at c. 20 mm working distance and at magnifications of × 25 to × 500. Micrographs were stored as tiff files. For the more complex objects cited here, between 25 and 50 micrographs were taken for each object.

Traces of possible textiles were compared with reference images of similar forms found on metal surfaces. These included dendritic structures (tree-like crystal structures on metal surfaces that form as molten metal solidifies) (Fig. 6), and impressions formed during the casting process. For example, negative impressions were formed by contact with textiles during the casting process of silver ingots from the Cuerdale hoard, Lancashire (c. 903–905 CE) (Granger-Taylor, 2011, 82) and the inside of a brooch from the Kneep Viking burial, Isle of Lewis, Scotland (Welander et al. 1987, 161).

Mineralised textiles (organics, positive and negative casts) were documented according to yarn and weave structure following standard procedures (Emery, 1994; Walton and Eastwood 1988). With many of the textiles on the hoard objects preserved only as traces, a new terminology and method was devised to account for the textile traces's appearance and structure within metal corrosion products. This new terminology (Table 2) supplements the mineralised textile terminology defined by Janaway and reviewed above (Table 1) (Janaway, 1983, 1985, 1989).

Textile traces on the Galloway Hoard ranged from organic preserved textiles and mineralised textiles to petal shaped features occuring in regular, offset rows (Fig. 7). 'Petal shape' is a morphological description devised here to characterise physical traces of textiles on the surface of corroded metal objects. Petal shaped features are the remains of binding points, which are where in a textile the warp thread is bound by the weft thread or vice versa (Monnas et al 2021, 4). The binding point creates a slight elevation of the textile surface. It is this raised surface that touches the metal which, through processes of mineralisation and decay, leaves a petal shaped trace (see Fig. 8).

Petal shaped traces can be separated into two structures (Table 2). First, what are defined here as remnant textile surfaces which have up to 25 % thickness of the original textile. Because in effect the remnant textile is being viewed from the inside, any preserved yarn twist will be reversed. In addition, only one surface of the textile structure is available for analysis. A similar process of reversal and information loss occurs in cord-impressed ceramics (Adovasio, 2010, 10; Grömer and Kern 2010, 3137). Second are ghost textile surfaces, defined here as petal shaped scars in regular patterns of offset lines, with few to no remnants of fibre

Fig. 7. Composite bead pendant (71.5) partially wrapped in woven textile. Towards the base on the left is the end of a copper alloy pin from an adjacent brooch; the high level of copper ions in this area has caused the mineralised textile to look greener in colour (Image © National Museums Scotland).

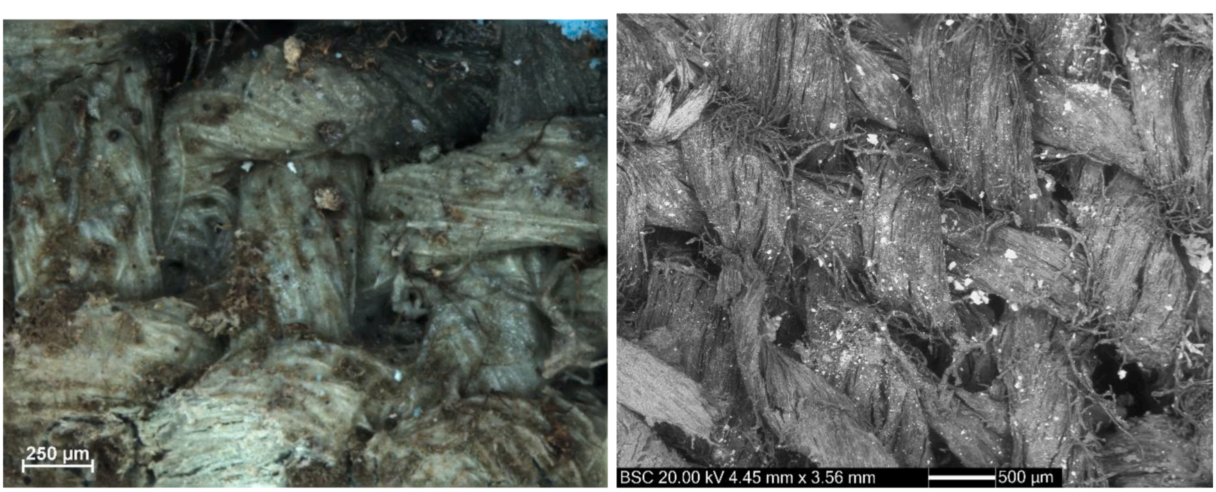


Fig. 8. a: Photomicrograph (71.12) and 8b: Back scattered electron images (SEM BSE) image (71.5) showing textile, threads and fibres preserved by association with copper ions. The raised 'binding points' can result in mineralised petal shapes on associated metal. (Image © National Museums Scotland).

or textile. Like remnant textile surfaces, ghost textile surfaces are where the binding points of a textile once touched the surface of the metal object. However, unlike the remnant textile surfaces, the textile is not preserved, or at most only a few fibres. No yarn twist is preserved; however, the offset pattern of petal-shaped rows indicates a textile structure. If sufficient remnant or ghost textile surfaces are preserved, it may be possible to measure the thread count, although this must be treated cautiously because the ephemeral structure may not represent the full number of threads. The terminology devised in this paper is defined and illustrated in Table 2.

Much information can be gained from remant and ghost textile surfaces as even small traces of textiles can preserve evidence of fibre, yarn, weave structure and position in relation to metal objects (Table 2). For certain weave structures, for example, pile fabrics this may not be

Fig. 9. Part of the composite bead pendant (71.5) showing from left: edge of silver coin [1]; decorated dark bead [2]; slightly corroded crown shaped silver casing with ghost textile on and near tip [3]; more organic mineral preserved textile to right [4] (Image © National Museums Scotland).

apparent because only one side of the textile is preserved. Thread counts from both remnant and ghost textiles surfaces must be extrapolated with caution, as it is possible that only part of the warp and weft remain.

Following analysis, decisions as to the possible retention or otherwise of traces in corrosion products were made in consultation with the museum curators, conservators, exhibition team and management.

3. Results

3.1. Composite bead pendant (71.5): Deterioration and preservation of woven bast fibres

The best preservation of textiles from the upper layer in the vessel was on the composite bead pendant (71.5, Fig. 7, Fig. 5). This object was made up of a large domed dark-coloured glass bead, decorated with fine twisted yellow spirals of glass melded into its surface. It had broken in antiquity and had then been encased in a crown-shaped silver setting soldered to a decorative perforated base. On the top of the bead was a pierced coin of Coenwulf of Mercia (died 821 CE) (R. Naismith pers. comm.), and the coin, bead and silver casing were held together with a silver loop on a rod running through each element and riveted at the base.

Photography on the day of discovery by the finders showed the composite bead pendant originally lay on its side, with the penannular brooch hoop below (Fig. 4a). The textile wrapping the composite bead also contained the broken end of a copper alloy pin from one of the Anglo-Saxon brooches in the vessel (71.14), now stuck into its surface (Fig. 7; Fig. 12).

3.1.1. Petal shape patterns seen in types of corrosion on metal surfaces in contact with woven textiles

Due to the range of mineralisation of the textiles on the composite bead pendant (71.5), it was possible to ascertain important information on the corrosion processes and appearance of ephemeral textile traces (Fig. 9).

Where the tip of the copper alloy pin was inserted in the textile, it was dark green and heavily mineralised. Further from this source of copper, the textile was a pale natural colour (Fig. 9, position 4) and then seemed to disappear altogether, except for a pattern of small petal shapes on the surface of the silver casing (Fig. 9 position 3; Table 2). This gave a clear picture as to how both remnant and ghost textile surfaces looked when mineralised and after the original textile had largely disintegrated. Following standard textile analyses (Emery, 1994; Walton and Eastwood 1988) to investigate the structure and spacing of the binding points, the textile was identified as plain weave with 16/13 threads per cm. The twist direction was identified in the preserved yarn and fibre of the remnant textile surface. Both warp and weft were woven with z-spun singles (noting these appear as s-twists) with a diameter of 0.56 and 0.48 mm. The ghost textile surfaces, further to the left in Fig. 9 position 3, have no preserved fibres or yarn. The results from observations and analyses of this object with its varied textile preservation were imperative for understanding the remnant and ghost textile surfaces.

3.1.2. Degrees of preservation in detail

Examination of the top of the silver casing on the composite bead using the SEM (Fig. 10) where the organic component of the textile had not survived provided further information about its degradation. The pattern is interesting; there are a series of regularly spaced petal shapes,

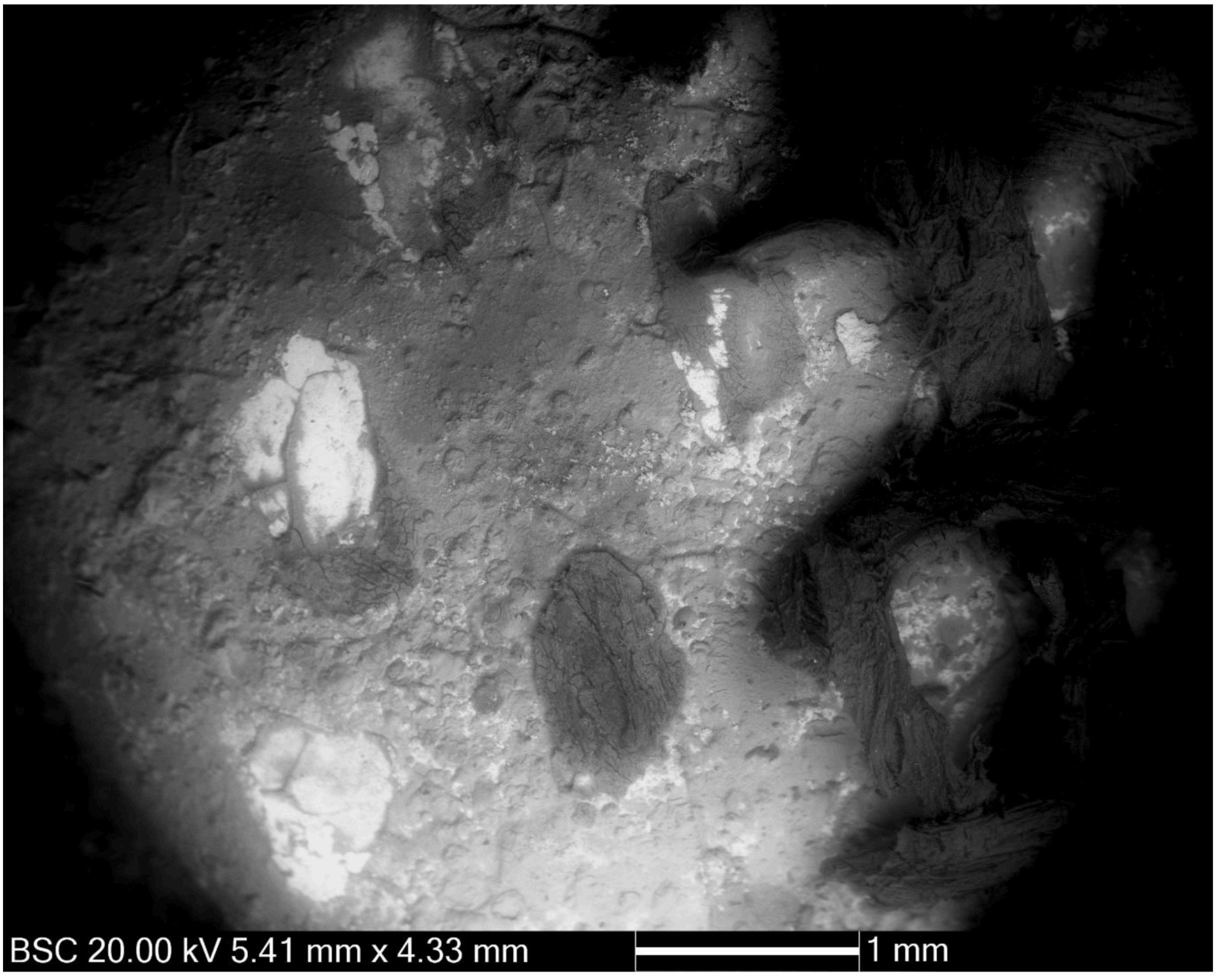


Fig. 10. SEM BSE image of the corroded area on the casing of the composite bead (71.5). The darker petal shapes are surviving organic threads - remnant textile surfaces; the lightest petal shapes are uncorroded silver – ghost textile surfaces (Image © National Museums Scotland).

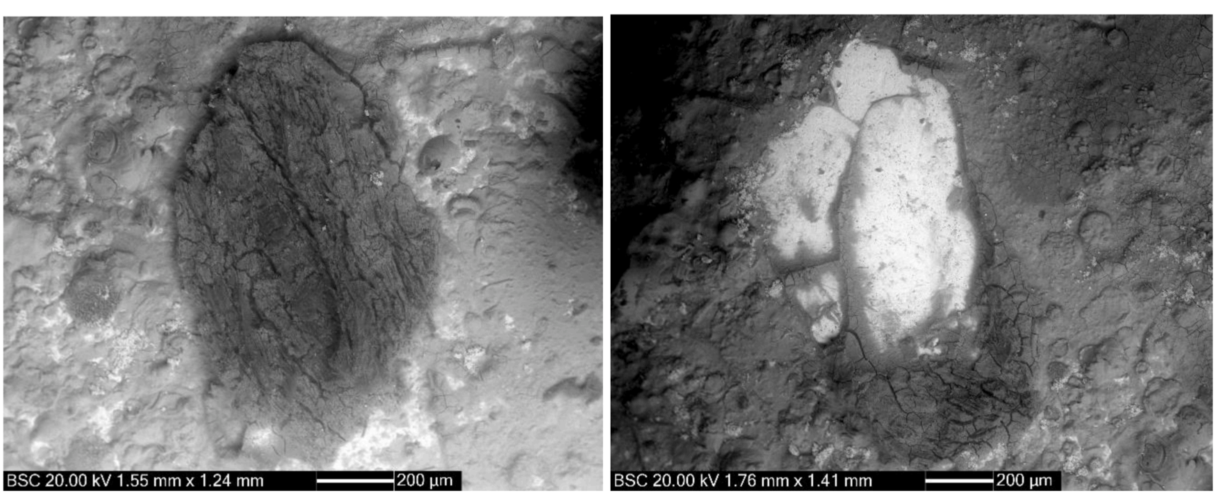


Fig. 11. a and b: Details of petal shapes, which are preserved were the binding points of the textile originally touched the metal casing of the composite bead pendant (71.5) (Image © National Museums Scotland).

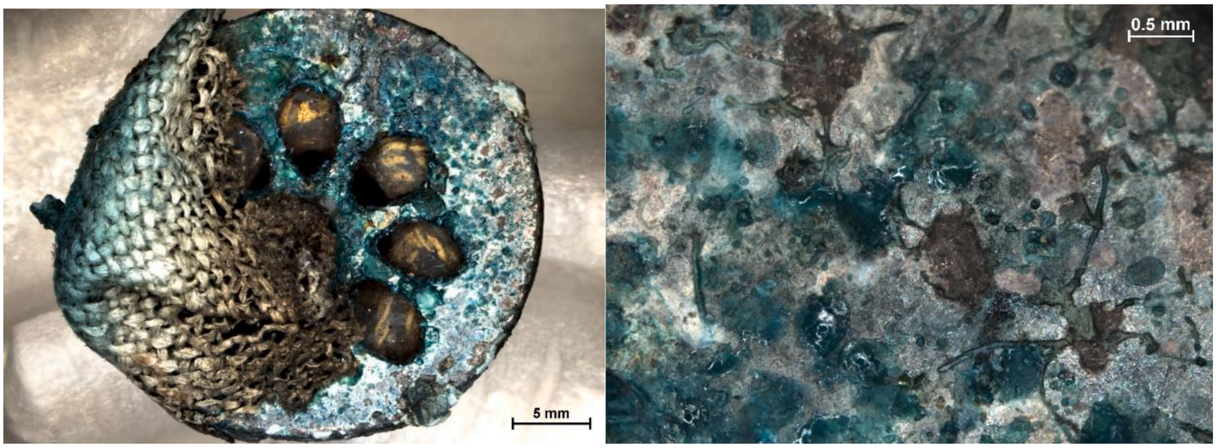


Fig. 12. a: Image of base of composite bead pendant where much of the organic textile wrapping has been lost, but some 'ghost' textile surfaces remained forming a pattern of faint dark grey/brown petal shapes in the corrosion products (71.5). Fig. 12b: detail of grey/brown-coloured petal shapes on the base (Image © National Museums Scotland).

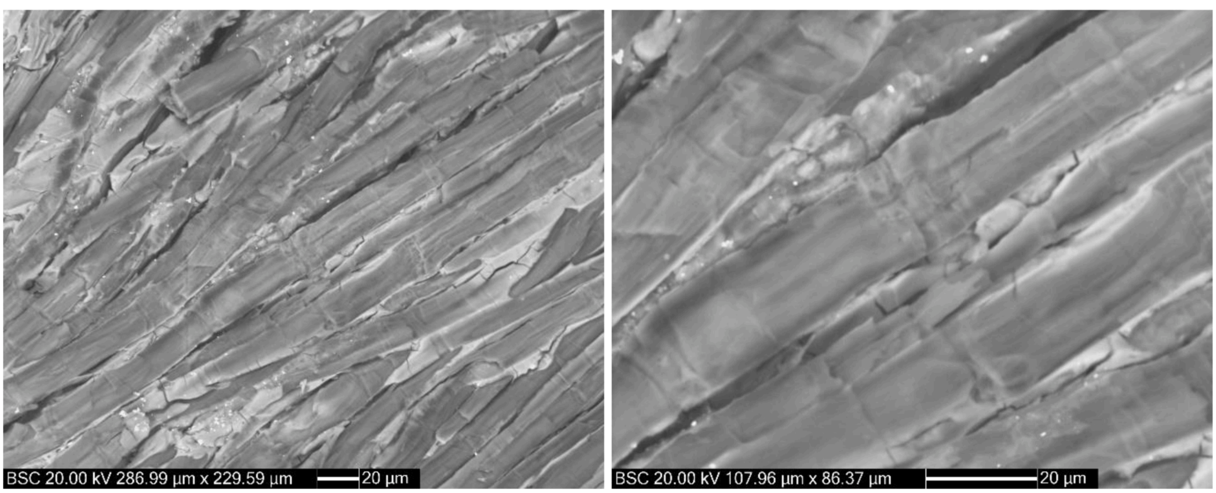


Fig. 13. a and b: Mineralised fibres; the nodes are characteristic of bast fibres (71.5) (Image © National Museums Scotland).

which represent where the binding points of the fabric were in contact with the metal. The preservation within the petal shapes shows considerable variation (Fig. 11a and b). The darkest areas are remnant textile surfaces and represent the remains of spun yarns and fibres. However, some of the petal shapes consist of bare metal, referred to as ghost textile surfaces. Here the areas of textile in contact with the silver had caused mineralisation of the fibres as identified, but these fibres had since become detached removing the superficial copper corrosion products from the surface of the silver, leaving bare uncorroded metal. The bare surface of the metal sometimes looked scarred from the process.

The proximity of organic material to the metal had promoted the preferential corrosion of copper alloyed within the silver and caused a mottled green appearance on the metal surface of the composite bead casing. This was especially visible on the base of the object (Fig. 12). Here, similar, faint petal shapes of ghost textile surfaces were observed, leading to the interpretation that the object was originally entirely wrapped in fabric.

Preserved fibres in remnant textile surfaces can be identified following standard procedures (e.g., Rast-Eicher, 2016). SEM BSE images of the mineralised and partially mineralised fibres of the composite bead pendant (71.5) show nodes that are characteristic of bast fibres (Fig. 13a and b). These are soft woody fibres obtained from stems of dicotyledonous plants and are characteristic of fibres such as flax, nettle or hemp (Timar-Balazsy and Eastop, 2020).

3.2. *Viking penannular brooch (71.9) – corrosion patches*

The Viking penannular brooch made from debased silver (71.9, Fig. 14), which was placed immediately below the upper layer of beads and curios in the vessel had various patches of corrosion on its upper surface. There were several colours and textures amongst these, but photographs from the excavation could match the patches to where individual objects had originally been placed on the brooch hoop (Fig. 4b and 5). The corrosion on the left-hand side of the hoop, where the composite bead pendant was originally positioned within the vessel, had varied and diagnostic corrosion products on its surface (Fig. 14).

3.2.1. *Appearance of different surface corrosion products*

Some of the green/blue copper corrosion products on the brooch hoop had very little form (Fig. 15). However, the structure of small areas of textile within some of the corrosion products could be seen. Under magnification it was possible to see the characteristic petal shapes of ephemeral traces of textiles. These remnant textile surfaces showed the directional z-twist qualities of yarn (appears as s-twist), and binding points of a woven textile.

Fig. 14. Viking penannular brooch hoop with corrosion patches (71.9) (Image © National Museums Scotland).

3.2.2. Detail of fibre preservation directional casts, organic survival

Analysis of the penannular brooch hoop using scanning electron microscopy with back scattered electron images (SEM BSE) uncovered the extent and structure of the preserved corrosion products and fibres (Fig. 16). These images defined the density of the materials and transformed our understanding of the Galloway hoard textiles.

A detailed image of one of the grey textured areas with SEM BSE (Fig. 17) shows a longitudinal pattern of tubes within the corrosion products where the fibres once lay and are now mostly preserved as a negative cast. The dark tubes in the micrograph are preserved fibres (Fig. 17).

Negative casts are less frequently seen with mineralised copper and occur where the inside of the corrosion crust reveals the morphology of the outer surface of the textile. However, corrosion products visible on the Viking penannular brooch have preserved both negative and positive casts (71.9), and the SEM micrographs (Fig. 18a and b) illustrate how these two types of mineralisation appear.

3.2.3. Identical area on composite bead pendant and penannular brooch

Through this analysis, it was possible to identify how a mineralised textile wrapping one object resulted in ephemeral traces on the surface of another object. The image on the right of Fig. 19 shows the remnant textile surface on the Viking penannular brooch. Turned on its side it directly matches the SEM image (Fig. 19, left) of the mineralised textile on the composite bead pendant, with the top surface or mineralisation removed leaving the bast fibres exposed. This match indicates the precise position in which the composite bead was placed on the brooch hoop, and also illustrates how the objects had broken away from each other, leaving the top layer of mineralised textile from the composite bead pendant as a remnant textile surface on the Viking penannular brooch. This surprising result shows how valuable it is to investigate ephemeral traces of textiles, and the precision in which the relationship between metal objects and textiles can be determined (see discussion and conclusion).

An SEM BSE micrograph of a section through a bundle of mineralised fibres on the composite pendant allowed examination of the fibres (71.5). Individual cross-sections and broken fibres can be seen protruding from a network of tubes created by copper corrosion products surrounding individual fibres (Fig. 20a and b).

3.3. Rock crystal sphere (71.4)

Analysis of petal shaped patterns on the composite bead pendant (71.5, Fig. 5) and the Viking penannular brooch hoop (71.9) allowed a confident interpretation of these features as textiles. These results enabled further investigation of metal corrosion products on objects from the top layer of the vessel. This layer was removed by the finders of the hoard on discovery and little information about the ephemeral extant textiles seen on their original photographs survive. However, ghost textile surfaces were identified on the silver binding of the rock crystal sphere (71.4). From this pattern we were able to deduce that this object had been wrapped in a similar textile (Figs. 21 and 22a-c).

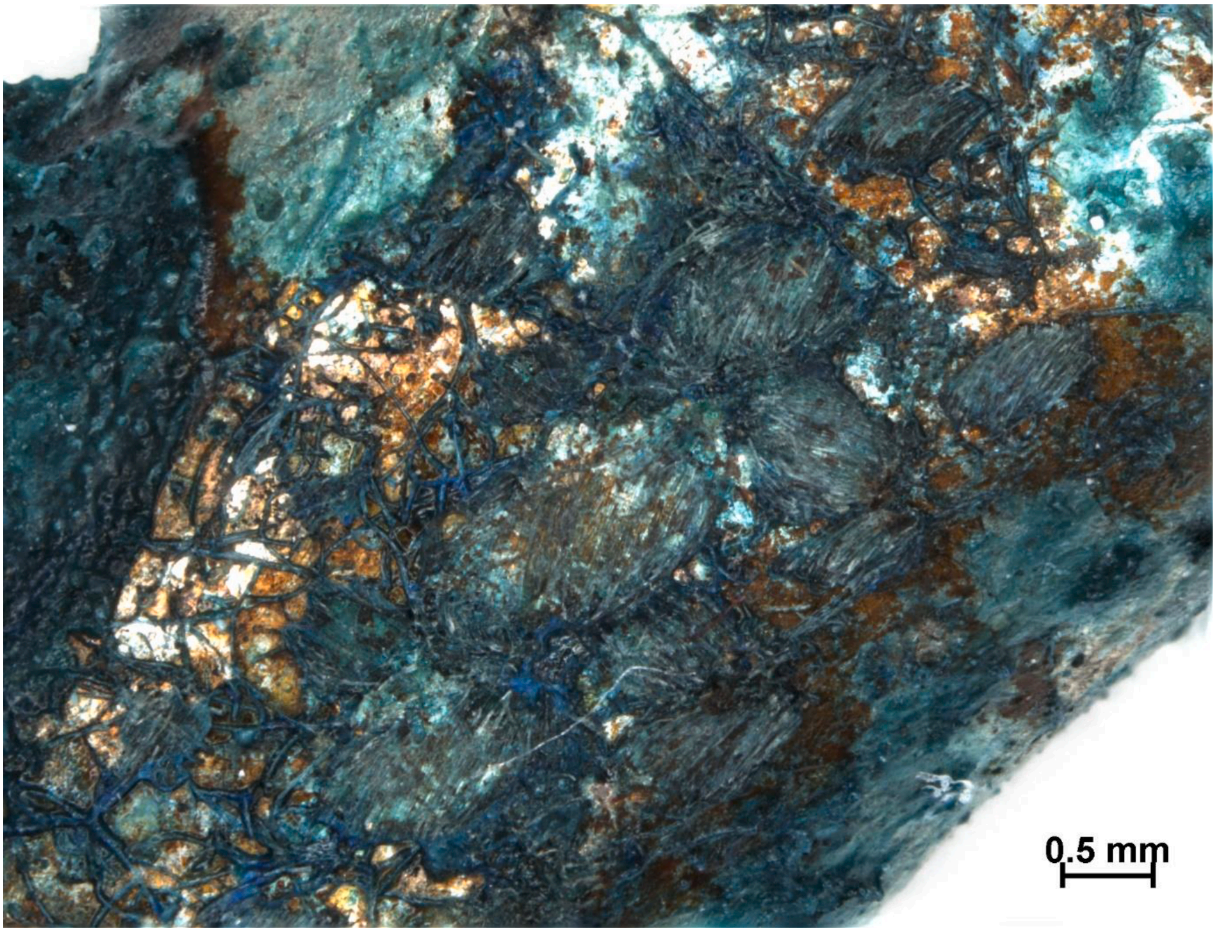


Fig. 15. Micrograph showing an area of corrosion with remnant textile surface on the Viking penannular brooch hoop (71.9). This portion of the hoop was originally placed under the composite bead pendant in the vessel (71.5, Fig. 5) (Image © National Museums Scotland).

3.4. Hinged strap (71.24) and disc brooch with niello (71.12)

Examination of several Anglo-Saxon brooches further down within the vessel showed they were not wrapped in textile. However, those placed adjacent to textile wrapped objects developed patches of green corrosion where they were in contact with organic materials. Mostly these were present as indistinct green corrosion products, but on one of the hinged straps (71.24, Fig. 23) and one of the brooches (71.12, Fig. 24) there were small areas of positive cast mineralised textiles. This result is significant because it allowed the observation that copper corrosion was enhanced where the metal objects were in contact with organic materials, such as textiles.

On one disc brooch decorated with niello (71.12) (Fig. 24), remnant textile surfaces with their characteristic petal shapes were again discernible, containing preserved, degraded organic fibres. It was noted that the preservation of adjacent textiles mainly remained where the niello (silver/copper sulphides) had been inlaid into the brooch surface, rather than on corrosion on the silver itself. This indicates that in this instance the higher levels of copper in the niello had been instrumental in preserving textile (Fig. 25; Fig. 26) (Table 3).

4. Discussion

In 2006, Peška and colleagues proposed a new sub discipline, the ‘archaeology of organic residuals and traces’, focusing on evidence of organic materials in metal corrosion products (Peška et al., 2006, 40). They suggest that rather than being exceptional, when metal objects corrode in close proximity to decaying organic materials (e.g., wood, cord, textile, plants, insects, human skin) these materials are *likely* to leave residues and traces in the metal corrosion products (Peška et al., 2006, 5). While the optimism of this view may be questioned, the preservation of textiles in the corrosion products of copper and iron objects is sufficiently frequent to be central to numerous major studies of archaeological textiles (Bender Jørgensen, 1992; Banck-Burgess, 1999; Rast-Eicher, 2008; Gleba, 2017). As metal corrosion products are more systematically studied, for example in combination with use wear studies to investigate wear and materials (e.g. Caricola et al. 2022), the question of identifying materials such as textiles from faint traces has become more pressing. Based on the research presented here, we recommend the default position should be that organic materials, such as textiles, might well survive in corrosion products, and corroded objects should be systematically examined and recorded before major conservation, handling or cleaning of any kind.

The Galloway Hoard, with its varied metal corrosion products ranging from fully mineralised textiles to unusual vestiges, provided an ideal example of how to identify ephemeral traces of textiles. Different microscopic equipment allowed for versatility and depth in approach to understanding organic remains.

The Dinolite offers a high degree of flexibility; it is portable and can easily be set up to work on laptops, so the person and equipment can go to the object. Its size and adaptability mean it is very good for examining areas on large objects which cannot easily fit under a bench microscope or cannot be moved for a range of logistical reasons. For these purposes it is an excellent tool for scoping work and identifying facets of artefacts that need further examination with laboratory equipment.

The Z-stacking capacity of optical microscopes has revolutionised the

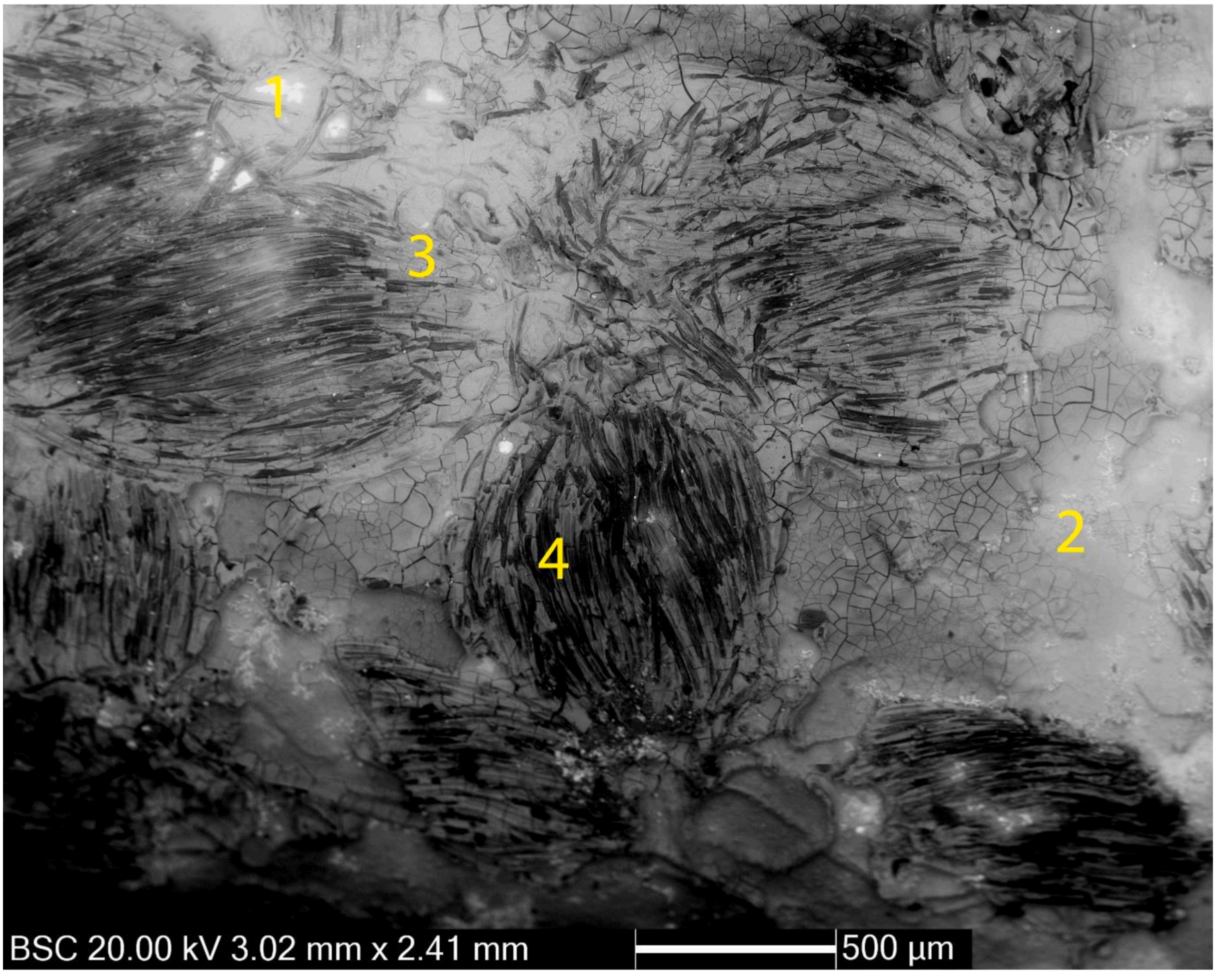


Fig. 16. SEM BSE image of remnant textile surface with its characteristic petal shape features preserved on the Viking penannular brooch hoop (71.9). The lightest patches represent silver metal [1], mid-grey shades are copper corrosion products overlying the silver [2]. Grey areas with a textured surface reveal negative casts of individual fibres within the corrosion products [3] (see example of detail in Fig. 17). Darker streaks represent partially preserved organic fibres within the corrosion layers [4]. (Image © National Museums Scotland).

quality of images taken from three-dimensional artefacts. Images in colour which can focus on multiple depths allow for a level of recording and understanding which could only be achieved formerly with numerous photographs or diagrams and are an important resource for analysis, records, publications and displays.

SEM imaging adds a further dimension to the study of this material. The depth of field and high magnification achievable allow images clear enough to identify individual fibres without necessarily sampling the objects. Lower vacuum settings allow for objects to be examined whole within the chamber without the need for a conductive coating (Davis, 2003). The resultant back-scattered electron images (SEM BSE) from this mode give an indication of the atomic mass of the material examined, for example the largely dark fragments of organic fibres within a lighter looking metallic corrosion crust.

The presence of textile wrappings and their possible religious connotations open larger questions about Viking age hoarding and hoarding in general. The Vale of York (British Museum Report 2010) and Halton Moor hoards (Franks, 1928), found in Britain, were both predominantly bullion based, consisting primarily of silver arm rings, ingots and coins; and both were contained in Carolingian vessels. Containers such as these indicate the potential significance, religious or otherwise, of their deposition as possible reliquaries (Ager, 2020), through the histories, provenance and previous uses of such containers. Through increased knowledge of the full material composition of their contents, including textiles, such hoards can be better contextualised beyond their bullion value.

In the case of the Galloway Hoard, these results proved that two items, the composite bead pendant and crystal sphere, were wrapped in textiles. Further items, a penannular brooch, hinged strap and disc brooch were identified as in contact with textiles. It is worth noting that lower down in the vessel, gold and silk items were wrapped in fine leather and complex silk weaves (Goldberg and Davis 2021), whereas the objects at the top, including those presented in this paper, all appear to have been wrapped in simple weaves made from plant fibre. These appear to be fragments of larger textiles, probably reused as wrappings, which also must have had a history for their previous use and manufacture. The presence or absence of textiles within the same assemblage is also noteworthy. Perhaps it is telling is that the obvious dress items in the vessel, the later Anglo-Saxon Trewhiddle style brooches and hinged straps tightly packed below the Viking penannular brooch, do not appear to have been wrapped.

In terms of understanding the Galloway Hoard, this investigation has increased our knowledge of the number of objects that were wrapped in textiles within the vessel. This has led to rethinking of how the hoard was prepared and buried, and its wider social or historical significance. In some places even the entire degradation of the textiles has left clues

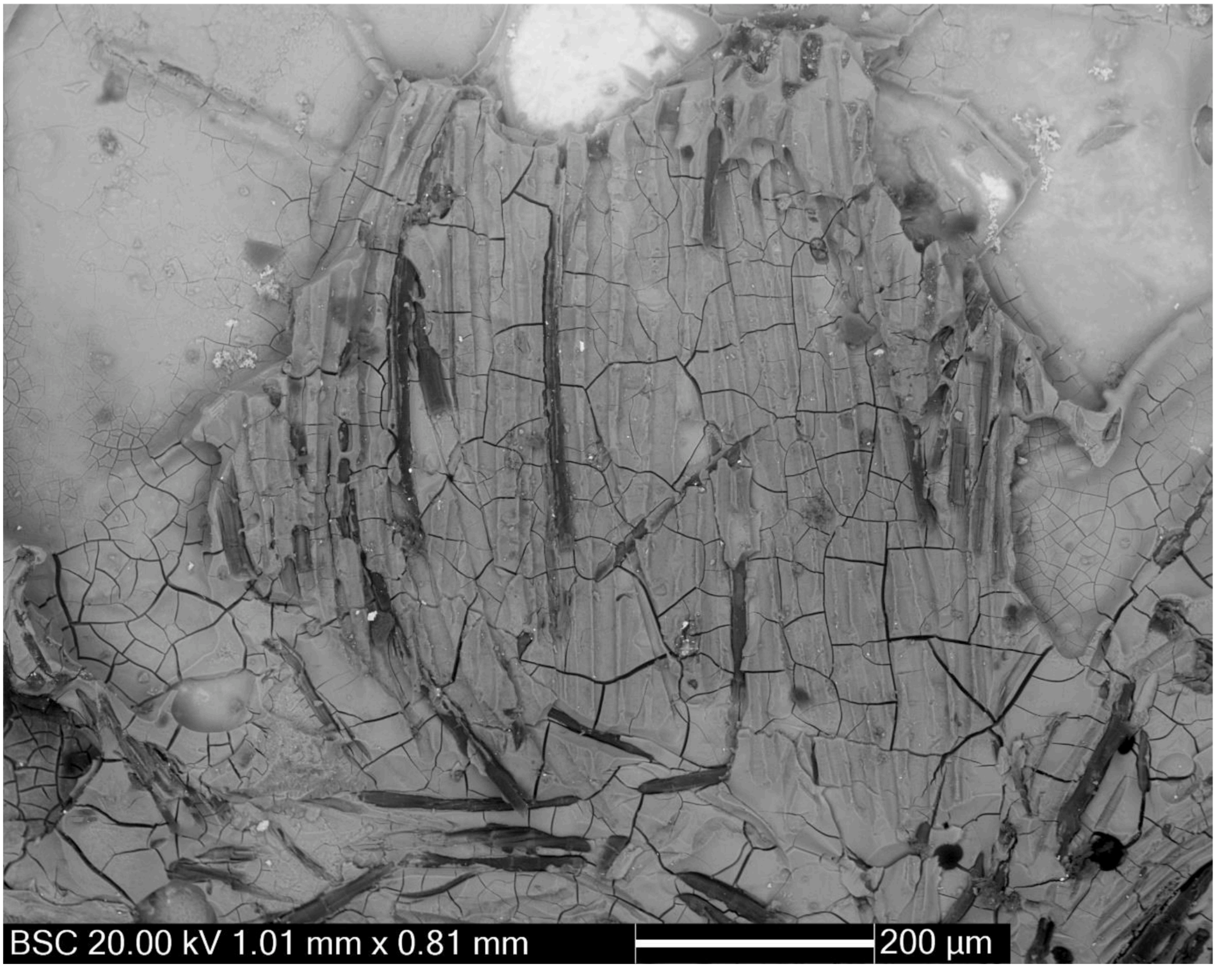


Fig. 17. SEM BSE image of a remnant textile surface with a characteristic petal shaped area of corrosion. The lighter longitudinal lines, seen in shades of grey, are metal corrosion products and show where individual fibres were positioned and have become negative casts. The dark streaks are organic preserved fibres (71.9). The materials appear different shades in the scanning electron micrograph (Image © National Museums Scotland).

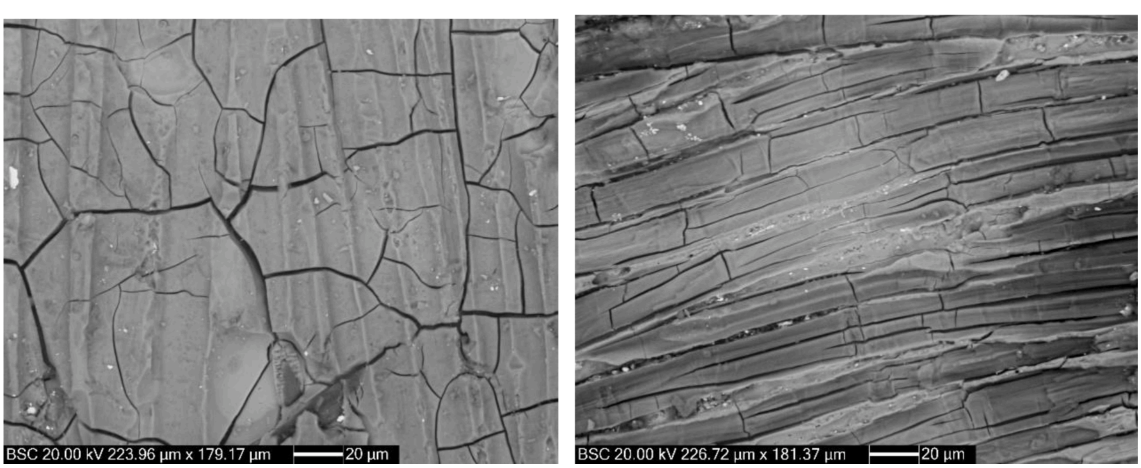


Fig. 18. a and b: SEM BSE images of negative casts preserved as longitudinal lines (left) and positive casts showing the mineralised fibres lying horizontally within copper corrosion products (right) (71.9) (Image © National Museums Scotland).

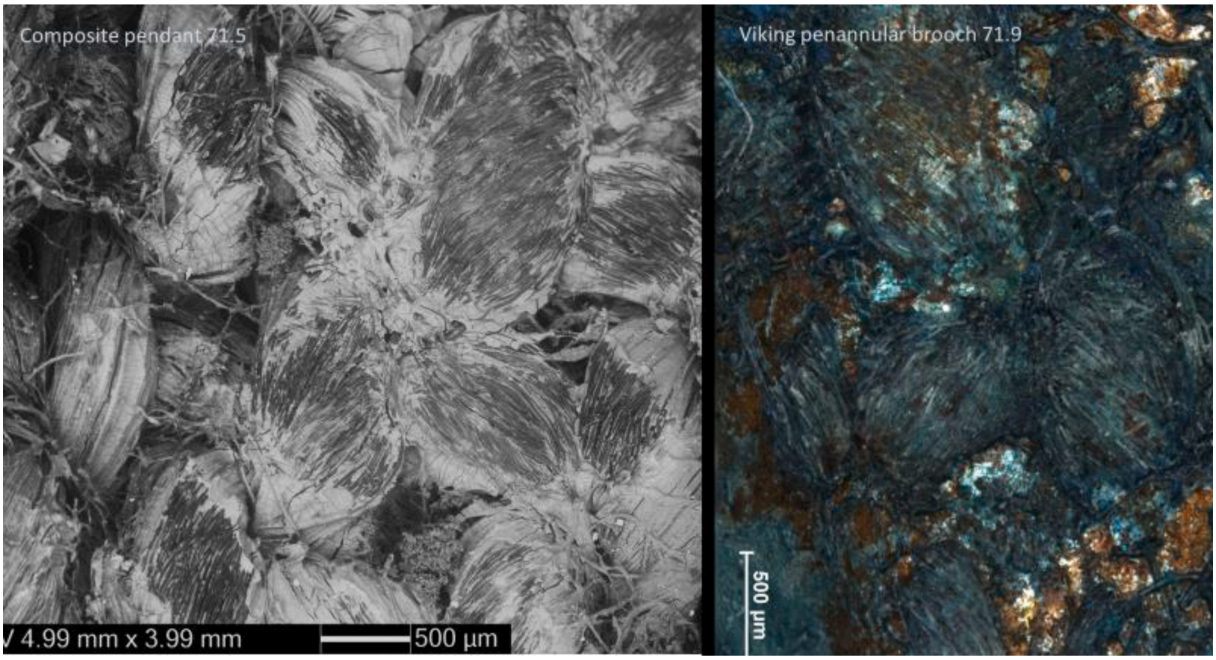


Fig. 19. SEM BSE image of the composite pendant (71.5) directly mirroring the image of fibres on the Viking brooch hoop (71.9) (Image © National Museums Scotland).

Fig. 20. a and b: Cross section of copper corrosion products containing a bundle of mineralised fibres preserved in situ on the composite bead pendant (71.5) (Image © National Museums Scotland).

on the metal surface as to where these once existed. These results are important; they add new evidence for the wrapping of individual objects within this hoard and corroborate historical evidence for the practice of wrapping items such as amulets of relics in the early medieval period (Smith 2014, 82). There are known examples of textile wrappings such as the surviving contents of the portable altar commissioned by Gertrude, Countess of Brunswick (d. 1117) (Smith 2012, 147), or the medieval relic textile bundles from Lower Saxony in the British Museum (1902–0625-1-ab). Finds such as these are usually preserved in church treasuries. Textiles were precious materials and could be amulets or relics in themselves, through association with cults and clothing of saints. Textiles were present in the graves of Early Medieval saints, such as Saint Cuthbert in Durham, England (Battiscombe 1956), and Saint Severin, Cologne, Germany (Schrenk, 2005, 102). The Galloway Hoard textile results provide opportunities to significantly change our understanding of wrapping hoards, relics and similar items that have been missed in the past.

5. Conclusion

The Galloway Hoard, with its combination of preserved textiles and corroded metal surfaces provided a rare opportunity to examine and securely identify ephemeral traces of materials in corrosion products that no longer had the appearance of textiles. To do this, the authors devised a microscopic method and novel terminology to identify and record faint traces of textiles. Using optical microscopy and scanning electron microscopy in backscatter mode (SEM BSE), petal shaped features observed on several objects in the hoard were identified and defined as remnant or ghost textile surfaces. This new terminology adds to that of positive and negative casts used to define mineralised textiles

Fig. 21. The rock crystal sphere (71.4, Fig. 5) within its silver frame. A patch of petal shaped corrosion can be seen on the lower left-hand quadrant of the top of the casing revealing a ghost textile surface (Image © National Museums Scotland).

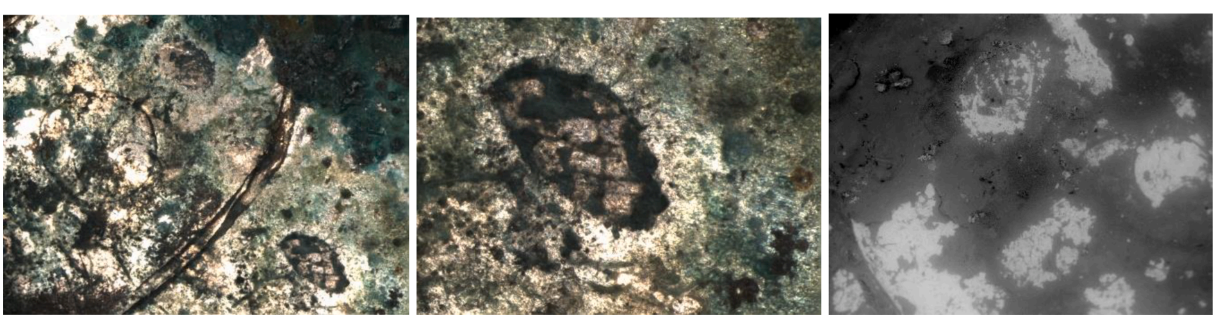


Fig. 22. a, b, and c: Photomicrographs and SEM BSE of the ghost textile surface on the silver frame encasing the rock crystal sphere (71.4); seen as light-coloured patches by SEM BSE (Image © National Museums Scotland).

by Janaway (1983, 1985, 1989). The analysis and description of remnant and ghost textile surfaces here can be used to identify ephemeral traces of textiles on other corroded metal objects.

Based on this research, it is recommended that all metal hoards with corrosion products are examined and documented to search for ephemeral traces of textiles before objects are handled or cleaned. Any traces need to be recorded with the best quality laboratory microscope available, preferably high-resolution, using z-stacked digital images and/or SEM, accompanied by written descriptions using the terminology presented here. Dinolite or similar portable microscopes are suitable for preliminary assessment and field recording, or where other options do not exist.

The interaction of metals and organic material in archaeological hoard deposits is notable. The mineralisation of the textiles and the corrosion of the metals were interdependent in forming these remains which survive in their present state due to the interaction between different materials, both organic and inorganic, during degradation of the assemblage. The myriad of both known and unknown factors contributing to preservation of the organics varied considerably - even for similar objects from the same context - and our understanding of the high level of variation has been important in recognising some of the more evanescent remains. Although the organics are the main feature explored in this paper, the synergetic interplay of chemical and biological degradation has also affected the corrosion of the silver in very specific ways, and the preservation of the niello in others; both features which are worthy of further study.

Fig. 23. a and b: Positive cast of textiles preserved in copper corrosion products on a hinged strap (71.24). the morphology of the individual fibres is more difficult to determine when completely encrusted (image © National Museums Scotland).

Fig. 24. a and b: The corrosion crust can be seen forming on the surface of the fibres attached to a disc brooch (71.12) (Image © National Museums Scotland).

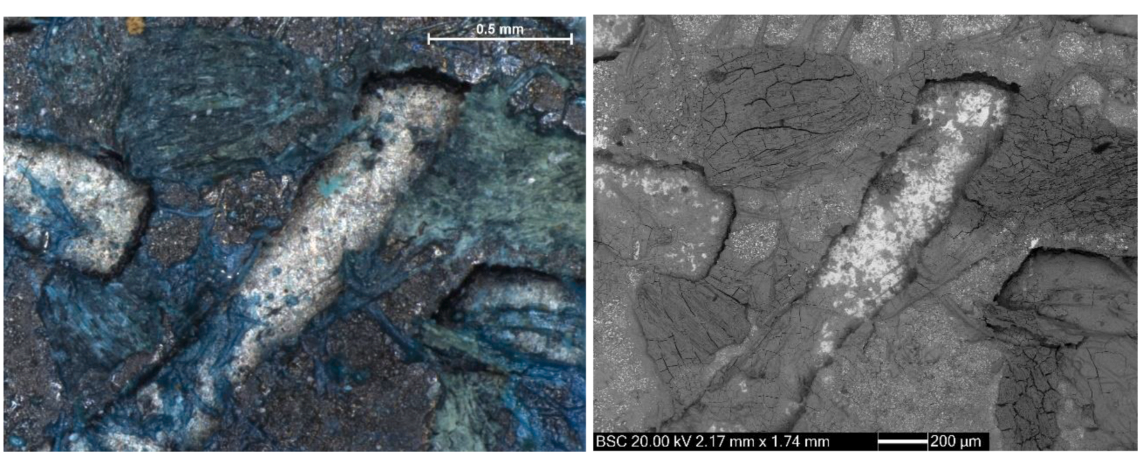


Fig. 25. a and b: a: Photomicrograph b: SEM BSE of petal shapes containing the mineralised bundles of fibres denoting where the binding points of this remnant textile surface were in contact with the brooch. In both images the niello appears mid grey and the light grey material is silver. With light microscopy (a) the petal shaped copper corrosion products of the remnant textile surfaces are green/blue. Using SEM BSE (b) the petal shaped are mid-dark grey and have a cracked appearance (Image © National Museums Scotland). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Fig. 26. Inlaid niello decoration on the silver brooch (71.12): the minerally preserved fibres survive preferentially on the copper rich area of niello rather than the surrounding silver (Image © National Museums Scotland).

Table 3
Results of mineralised textile analysis.

Artefact and Number	Materials	Form of mineralised textile	Textile results
Composite bead pendant (71.5)	Glass bead, debased silver frame for bead, silver suspension loop, silver coin (Coenwulf)	Ranging from organic preserved textile with limited biological decay, remnant textile surfaces with mineral impregnated fibres and binding points, to scars of ghost textile surfaces where mineralised textiles had formed and detached.	Plain weave textile wrapping whole composite bead pendant.
Viking penannular brooch (71.9)	Debased silver	Remnant textile surface consisting of petal shaped pattern of binding points and fibres on surface of metal.	Not wrapped in textile. Remnant textile surface formed through proximity to textiles from adjacent object (Composite bead pendant 71.5).
Crystal sphere (71.4)	Quartz crystal, debased silver frame for crystal	Mostly ghost textile structures across several areas of silver frame. Limited organic preservation of mineral impregnated fibres, partial preservation of weave as petal shape pattern on surface of metal.	Probably wrapped in a textile.
Disc brooch with niello (71.12)	Debased silver, niello, copper alloy pin and catch plate on reverse	Positive cast of mineralised textiles, adhering through proximity of textile from adjacent object. Partial preservation of remnant textile surface on metal and niello.	Not wrapped in textile. The positive cast of a textile and remnant textile surfaces formed through proximity to textile wrapped bundle inside the vessel.

Such records and results could significantly alter current understanding of hoards, which are predominantly discussed as metal deposits across archaeological periods (e.g., Naylor and Bland 2015). The identification of multiple textile wrappings in the Galloway hoard allowed for a new interpretation of the objects within the upper layer of the vessel, leading to questions about the presence of textiles whether for protective wrappings, bundles or in association with relics. There are many historical examples of 'relics' wrapped in textiles in the medieval world especially within continental reliquaries and corresponding to historical evidence which provide relevant comparisons. With the repeated focus on metals and other inorganic materials in hoards it is possible we have misunderstood the phenomenon of hoarding, not only in the early medieval period, but in early societies in general. By better tracing the textiles in hoards using the method presented here, it is possible not only to find more organic materials, as envisioned by Peška and colleagues (2006), but to change the dialogue around the practices of hoarding and the significance of textiles and metal objects in past societies.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

No data was used for the research described in the article.

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