Conservation and Restoration, Textiles

From Fragment to Form

A Digital Study of 17th-Century Silk Textiles from the Palmhoutwrak

MA Thesis

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Foreword

The field of conservation and restoration of textiles is constantly evolving, shaped not only by advances in technology but also by the enduring need to preserve fragile materials that serve as silent witnesses to history. This thesis was born out of a fascination with the potential of digital tools to bridge the gap between past and present — to reconstruct, reinterpret, and recontextualize what time and circumstance have torn apart. It challenged me to combine my background in historical with conservation thinking and interdisciplinary, digital approaches. The result is more than just a reconstruction of a group of textile objects. This thesis demonstrates how digital heritage preservation can complement traditional conservation practices, offering new ways to interact with our material past. The techniques explored here represent tools that can help us recover not just the physical appearance of lost objects, but something of their original presence and meaning. This research stands at the intersection of past and future—honouring centuries-old craftsmanship while embracing contemporary digital possibilities, allowing us to see the past more clearly while building foundations for future research.

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Summary

This thesis investigates 17th-century silk textile fragments from the BZN17 shipwreck using digital reconstruction techniques. Through photogrammetry, Gaussian splatting, historical and material analysis, the hypothesis is developed that the 34 crimson silk fragments originally formed curtain panels and valances of an luxurious four-poster bed. The study demonstrates how digital visualization methods can reconstruct fragmented archaeological textiles, providing insights into 17th-century material culture while establishing methodological frameworks for future textile heritage conservation projects.

Abstract

This thesis addresses the reconstruction of fragmented 17th-century silk textiles recovered from the BZN17 shipwreck (Palmhoutwrak) through an interdisciplinary approach combining digital visualization techniques with historical and material analysis. The central research question examines what object these textile fragments represent and how they would have appeared originally.

The methodology integrates photogrammetry and Gaussian splatting to create detailed 3D models of 34 individual silk fragments while minimizing physical handling of the delicate materials. These digital techniques capture fine structural details and preserve organic fabric characteristics more effectively than traditional mesh-based modeling. The fragments underwent comprehensive material analysis including fiber identification, SEM-EDX, and liquid chromatography for dye analysis, revealing dyestuff combinations of American cochineal, kermes, and possibly Armenian cochineal—indicating access to global trade networks.

Historical comparative research examined the fragments' weave structure, embellishments, and dimensions against 17th-century visual sources and surviving textile examples. The rich crimson silk's material properties and elite craftsmanship suggested high-status ownership, perhaps accompanying a travelling person, serving as diplomatic gifts or simply luxurious imported wares.

The combined evidence strongly supports the conclusion that these fragments originally formed the curtain panels and valances of a seventeenth-century four-poster bed belonging to someone in elite circles. The group of fragments is illustrative of both aesthetic refinement and the (intended) owner's access to Mediterranean and transatlantic trade networks, providing valuable insights into 17th-century material culture and socio-economic contexts.

This research contributes to digital heritage preservation by demonstrating how computational approaches complement traditional conservation methods. The study establishes that severely fragmented archaeological textiles can be meaningfully reconstructed, offering modern ways to understand and restore damaged textile artifacts. The methodology provides a scalable framework for future archaeological textile reconstructions, aimed at futureproofing and democratising cultural heritage.

Despite limitations including poor lighting conditions and software constraints, the thesis proves that digital reconstruction serves as both research methodology and public storytelling tool. The reconstructed bed hangings function as windows into domestic life, material wealth, and global networks of the seventeenth-century world, visualising stories that the fragmented textiles alone cannot convey. This case study establishes methodological models for future digital reconstructions while highlighting the growing potential of digital tools for conservation and restoration in the textiles heritage sector.

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1. Introduction

1.1 Research questions

This thesis focuses on a group of 17th-century silk textile fragments recovered from the BZN17 shipwreck, also known as the Palmhoutwrak. The fragments are part of a rare and exceptionally well-preserved maritime textile find, yet their original form and function remain unknown. Reconstructing this fragmented object poses both a historical and methodological challenge, requiring an interdisciplinary approach that combines material analysis with digital reconstruction techniques. A crucial question in the conservation and restoration of archaeological textiles is how to reconstruct fragmented pieces into a coherent representation of their original form. This thesis seeks to answer the central research question: *What object are these textile fragments part of, and how would they have looked originally?* The fragments, discovered in a shipwreck, present both a material and historical puzzle. To accurately reconstruct the original object using 3D visualization, several sub-questions must be addressed.

First, understanding the nature of the object requires situating it within its historical and functional context. This entails examining what types of textiles and garments were commonly used aboard ships in the 17th century, as well as broader fashion trends and material culture of the time. By comparing the physical characteristics of the fragments—such as weave, fibre content, decoration, and construction methods—with known examples from museum collections and historical records, it becomes possible to hypothesize which types of objects these pieces may have belonged to.

Second, the process of digitally reconstructing the textile requires an analysis of how the fragments relate to one another. The 34 individual pieces must be assessed for potential joins, alignment of patterns, and structural coherence. This raises questions about the completeness of the textile: Are all essential components present, or are there missing sections that need to be inferred? Determining whether the textile is whole or partial directly influences the accuracy of the final reconstruction.

Finally, the methodological challenge of reconstructing a fragmented and degraded textile digitally must be addressed. This involves exploring advanced 3D visualization techniques, including photogrammetry, digital pattern-making, and computational textile modelling, to virtually restore the textile to a possible original form. The study will evaluate the advantages and limitations of these digital tools in conservation, considering how they can compensate for lost material, reconstruct missing sections, and accurately simulate texture and drape.

Together, these sub-questions will attempt answering the main research question. By first situating the fragments within their historical and material context, then piecing them together structurally, and finally reconstructing them digitally, this research aims to provide a historically and visually accurate 3D representation of the original object.

1.2 Relevance to the field of conservation

Applying 3D visualization techniques to the reconstruction of fragmented textiles from a shipwreck has several advantages. First, digital modeling allows conservators to virtually piece together scattered fragments with minimizing the need to physically handle them, reducing the risk of further deterioration. Second, it enables the testing of different hypothetical reconstructions based on weave patterns, damage patterns, and known historical analogs. Third, these models provide an interactive tool for researchers and museum audiences, making textile heritage more accessible and visually interpretable. Last, by providing an academically substantiated hypothesis on the object these fragments belonged to, more knowledge is provided about the nature of the Palmhout ship's cargo, which in turn can form a basis for new ideas about its historical context and passengers.

By integrating historical analysis, textile conservation methodologies, and digital reconstruction techniques, this research contributes to the growing field of digital heritage preservation. It demonstrates how computational approaches can complement traditional conservation efforts, offering new ways to interpret and restore damaged textile artifacts. Given the increasing adoption of digital methods in heritage conservation, this study aligns with current trends in the field and provides an innovative approach to understanding and reconstructing lost textile heritage.

1.3 Methodology and structure

The methodology for this research combines digital reconstruction techniques with historical analysis to virtually restore the fragments using 3D visual imaging techniques. While the fragments seem to be in relatively good condition and can be handled, minimizing physical contact remains a priority. A digital approach minimizes handling while allowing for an accurate reconstruction of a possible original object and state. Photogrammetry and Gaussian Splatting are used as primary methods for recording image data of the fragments, followed by fragment analysis and comparative historical research.

Photogrammetry, the process of creating 3D models from high-resolution photographs, was used to document each fragment in detail. It captures fine structural details, providing essential data for reconstruction. Photogrammetry is a non-contact method that avoids potential damage to the fragile material while still generating highly detailed models. Aditionally, Gaussian Splatting was used to reconstruct the textile in three dimensions. This emerging technique differs from traditional mesh-based 3D modelling by representing surfaces as a dense cloud of data points, which can more accurately capture fine details and complex textures. And in contrast to the model derived from photogrammetry data, which utilizes a rough model and an image wrap to represent the object, this technique creates a more detailed model that combines geometry and material information simultaneously. This approach is particularly useful for textiles, as it can preserve the organic movement/shape and transparency of fabric without the rigid triangulation constraints of conventional 3D scanning.

In addition to creating a detailed digital model, the fragments and their decoration have been analysed to determine the potential relationships between the 34 fragments. The results from this puzzle were then compared to historical textile references from the 17th century to determine their likely function and original appearance. This comparative research considers material and visual properties, to compare contemporary decoration, interior fashions, historical context and known artifacts in textile collections.

Material analysis plays a crucial role in understanding the composition, weave structure, and potential dyes or finishes used in the textiles. Samples have been taken for fibre identification through microscopy as well as SEM-EDX and liquid chromatography for dye analysis. This data informs the digital reconstruction by providing insights into how the textile originally looked and functioned and what socio-economical context it was a part of. For the reconstructing process, different softwares were considered. Blender is a good all-round, open-source and intuitive 3D-modelling software and Agisoft Metashape will be used for generating the initial 3D models from the captured images. Gaussian Splatting will then be applied to refine the reconstruction, as its point-cloud-based approach offers a more flexible and high-fidelity representation of organic materials compared to traditional mesh-based models.

This thesis will start out by providing an introduction into the group of fragments found in the BZN17 shipwreck and the ships context, both historical and present day. Then it will give an overview of two aspects of the academic discourse concerning digital visualisation in cultural heritage, specifically the textile context. The first aspect reviews considerations on how and why digital techniques are a hot topic in the textile heritage sector. The second discusses the methodologies and techniques that are currently available and have been used by conservators and heritage experts, accompanied by multiple examples of relevant case studies. The next chapter builds on this theoretical framework by explaining the methodology of this project and also presents a preliminary study that was conducted. This is followed by the chapter on the analysis of the fragments and comparative historical research that provides evidence for their original purpose. The last chapter discusses and reflects on the process, with its results, promises for the future and regrets.

2. Case study BZN17

This chapter looks into the historical context of the textiles discovered in the BZN17 shipwreck, also known as the Palmwood Wreck, or Palmhoutwrak in Dutch. The 17th-century shipwreck was discovered off the coast of Texel in the Netherlands, and is an extremely significant discovery in the field of textiles heritage. Identified as the seventeenth wreck found in the Burgzand Noord area, it was first located in 2009, but it gained international attention in 2016 with the discovery of an exceptionally well-preserved textile collection. The ship likely functioned as a medium-to-large trading vessel that sank around 1640 while anchored at the Rede van Texel, a historically significant maritime hub where Dutch East India Company (VOC) and other European ships gathered before embarking on long voyages. One of the most remarkable aspects of the wreck is the state of preservation of its artifacts. Due to the anaerobic underwater conditions, organic materials, including textiles, leather bookbindings, and wooden objects, remained in unexpectedly good condition. Among the finds was an elaborate 17th-century silk gown, which received widespread media coverage and was even nicknamed the "royal gown" due to its extraordinary craftsmanship and presumed association with a high-status individual. It is one of the most unique and extensive collections of early modern textiles discovered under the sea. The discovery of the Palmhoutwrak has significantly contributed to the study of 17th-century maritime trade, fashion, and textile production, as preserved textiles from this period are exceptionally rare. The wreck and its cargo offer insights into material culture, social status, and the role of Texel as a logistical center in global trade networks. Ongoing research, involving institutions such as the University of Amsterdam, Rijksmuseum, and Museum Kaap Skil, continues to analyze the artifacts, with particular attention to textile conservation, historical reconstruction, and digital preservation techniques.[1]

Among these textiles is a group of 34 fragments (see appendix 10.1) of a bright red plain weave silk, with the same colour fringe trims and cords knotted into frogging. These fragments will be the subject of this thesis.

[1] M. de Bruijne and S. Telleman, “Wrakken in de Waddenzee bij Texel: Textielschat uit zee”, *De archeologische kroniek van Noord-Holland* (Haarlem, 2016), 167-176; Marijke de Bruijne and Sjoukje Telleman, "Textielschat uit zee: Een literatuurverkenning naar textiel uit maritieme context'," *Jaarboek Kostuumvereniging: 'Kostuum'* (2016).

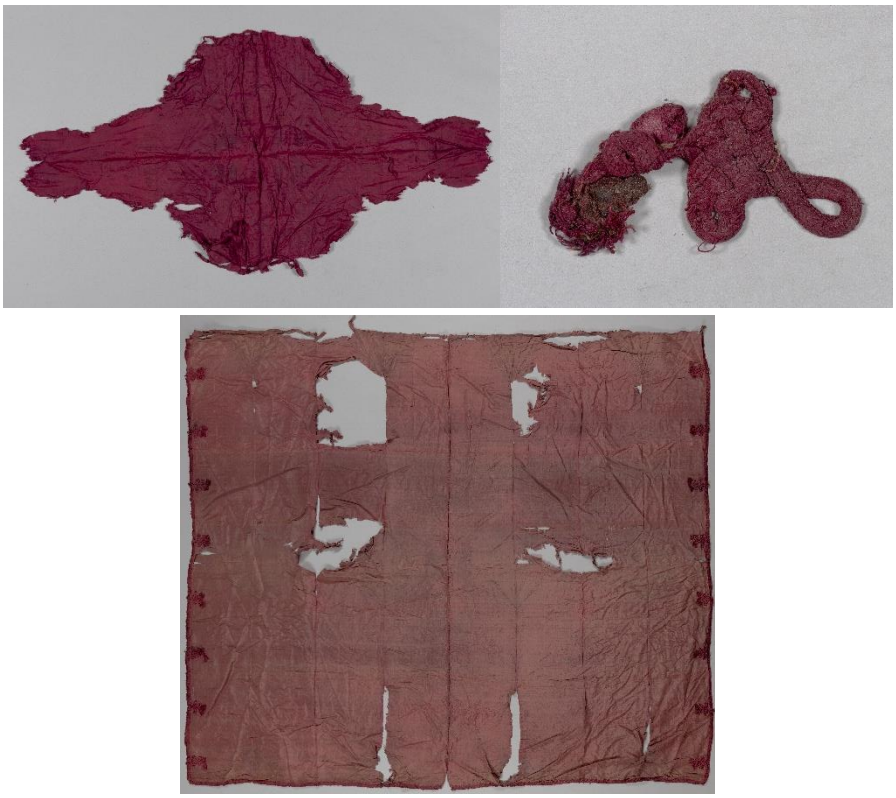

Figure 1. A selection of the BZN17 fragments. Top left: 6263-051, top right: 6261-015, bottom: 6263-102. All images courtesy of Huis van Hilde.

The collection is representative of a time when European elites displayed their wealth through the acquisition of textiles and other luxury goods and consists of garments, interior textiles and accessories. Most of the discovered fragments are made of a fine red silk, and many of them are decorated with metal threads. This indicates that these objects were luxury goods and many of them were quite 'exotic' in nature. Textile objects of this type would have been extremely precious and were often used as gifts or payment in kind.[2]

Many of the textiles found in the Palmwood shipwreck have been preserved exceptionally well, despite having spent centuries on the bottom of the sea. Despite might not be the correct state in this case, as these conditions – the low oxygen levels, and stable and cool temperatures under the seafloor of the Wadden Sea – are likely the cause of this extraordinary preservation, as they slowed down the inherent degradation of the textiles. And because they are so well-preserved, they allow very valuable opportunities for research. This research has been going on for a decade and is extremely diverse, ranging from condition checks to material and construction analysis, as well as research into the historical background of this unique find. This 'freeze frame' provides new insights into the 17th-century, and by comparison with other historical sources let us get a closer look at what we thought we knew about the era and introduces us to the collections original owners and the people who interacted with it.[3]

[2] Kramer, Hanneke. *Diving into Details: Reconstructing the Research and Practices of the Textile Collection Found at Shipwreck Burgzand North 17*. Master's thesis, University of Amsterdam, 2017.

[3] Maarten van Bommel, "Chemical Analysis of BZN17 Textiles," Cultural Heritage Agency of the Netherlands (RCE), April 3, 2017; Savelli, Sandra. "Metal Threads in 17th Century Textiles: Art-technological Research and Characterization of Burgzand North 17 Metal Threads" (Master's thesis, Universiteit van Amsterdam, 2018).

2.1 The discovery of the Palmwood Wreck

The BZN17 wreck was discovered in 2009 by local divers from Texel. This region, the Burgzand area, was historically known as the Rede van Texel, an anchorage place where ships would pause their journeys. Because so many ships waited here, for instance for the right tides, inspections or to replenish their stores, and there were many storms, the area became a sort of ship graveyard. In 2014 the BZN17 wreck became exposed and it was now possible to dive to the wreck and retrieve parts of the ship's cargo. The local divers recovered around a thousand objects, among which were leather goods, wooden chests, metal objects and a large amount of textiles. The divers argued that it was better to remove the objects, as their now exposed situation left them vulnerable and may have kick-started the deterioration. It was not until later that the provincial authorities became involved and the objects were moved into care of the Province of North-Holland's archaeological department. The divers rinsed and stored many of the objects themselves before they were given to the province. In collaboration with the province, represented by the Huis van Hilde, the RCE and textile conservators affiliated with the UvA conservation programme started studying and further treating of the objects. This has been an ongoing effort. Currently many of the objects recovered from the wreck, also from later dives sanctioned by the province, are in storage at the Huis van Hilde and some of the highlights are part of an exhibit that gained international attention at Museum Kaap Skil.[4]

The wreck's nickname, Palmwood Wreck, derives from a cargo of boxwood (Buxus sempervirens), a dense and expensive hardwood often used in furniture making and tool handles. The presence of such cargo suggests the ship might have been part of trade involving the Mediterranean, possibly Italy, Southern France, or the Levant. This is further supported by the finding of canons, which were usually present on merchant ships sailing the Mediterranean to protect them from pirates and privateers, who were rampant in this region. The official designation, BZN17, stands for Burgzand Noord wreck number 17, in line with archaeological site registration in the Dutch maritime heritage system. [5]

Among the wreck's most high-profile finds is a full-length silk gown, likely (intended to be) worn by a wealthy woman. Its style is reflective of contemporary fashion trends, possibly modelled on English or French court dress. Along with the gown, multiple other garments have been found: such as a kaftan with Ottoman-style embroidery, fine silk stockings, cloaks, and bodices. The wide range of textile types and garment sizes suggests ownership by multiple individuals, possibly a family group or aristocratic household or that they were intended for trade purposes. In addition to clothing, the collection includes interior textiles (tapestries, bed hangings), a toiletry set decorated with metal thread, leather-bound books, and silver houseware. The collection of bookbindings is particularly revealing. Many are decorated with gold and heraldic insignia. One bears the coat of arms of the Stuart royal family, while another shows the Ostrogski arms from the Polish-Lithuanian nobility. This might mean that they had an owner that moved in elite, possibly international, circles, and could provide clues to the destination and origins of the ship's passengers.[6]

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[4] Kramer, *Diving into Details*, 2017; Archaeologische kroniek; Janet Dickinson, "Drowned Books and Ghost Books: Making Sense of the Finds from a 17th-Century Shipwreck off the Dutch Island of Texel." *The Seventeenth Century* 38, no. 1 (2023): 49–85.

[5] Dickinson, "Drowned Books and Ghost Books."; Archaeologische kroniek, 158-159; Arent D. Vos et al., *Wereldvondsten uit een Hollands Schip: Basisrapportage BZN17/Palmhoutwrak*, ed. Birgit van den Hoven and Iris Toussaint (Haarlem, 2019), 57, 71, 73, 372.

[6] Lambert D. Westera, "The Silk Dress and the Shipwreck: A 17th-century Wreck near Texel." *The Mariner's Mirror* 111, no. 1 (2025): 22–40; Savelli, *Metal Threads*, 2018; Dickinson, "Drowned Books and Ghost Books."

2.2 The travels of the Palmwood Wreck

Dendrochronological dating of the ship's timbers suggests it was built shortly after the winter of 1640/41. The earliest launch date is estimated around 1643, with construction possibly extending to 1645 or later. Artillery pieces on board—cannons cast between 1638 and 1640—add to this idea, as these weapons may have been reused or made as the plans of building a ship were finalized. The vessel is likely a Straatvaarder, a class of large Dutch merchant ships that sailed in the Mediterranean (the name refers to the Strait of Gibraltar). These ships were heavily armed and capable of defending their cargo against pirates or hostile powers. The presence of mastic resin, found only on the island of Chios, supports the hypothesis that the ship hailed an eastern Mediterranean port.[7]

An interesting, theory links the Palmwood Wreck to the entourage of Queen Henrietta Maria of England. In February 1643, she sailed from the Netherlands back to England, accompanied by two baggage ships. Historical newspapers reported that both ships were lost in a storm near Texel. While BZN17 is not definitively proven to be one of these, it may have been or it may have been a ship that salvaged cargo or passengers from a royal vessel before being itself lost in the same storm.[8]

The early modern period was characterized by an increase in mobility. Merchants, diplomats, clerics, soldiers, and artists travelled across Europe for reasons ranging from trade to education. Women, too, increasingly traveled, often in the context of courtly households or as part of marriage negotiations. The objects found aboard BZN17 reflect this increased mobility. The materiality of these items—not just their content or use—signals their importance in the self-fashioning of 17th-century elites. Books were signifiers of education and status, gowns markers of identity, wealth and virtue, and toiletry sets signifiers of refined private life. The coexistence of English, Dutch, and Central European elements aboard a single vessel points to a cosmopolitan lifestyle shaped by transnational networks. [9]

Texel's anchorage, the Rede van Texel, was one of the busiest maritime hubs of the Dutch Golden Age. Ships from the VOC (Dutch East India Company), WIC (West India Company), and independent merchants stopped here on their journeys to the Baltic, Iberian, and Mediterranean seas. The high density of shipwrecks in the area—including BZN17—testifies to both the extent and risks of this trade.[10]

The tragic sinking of BZN17, likely in a storm, froze in time this collection of personal and commercial goods. Its survival into the 21st century offers an unparalleled look into the entangled histories of early modern travel, taste, and trade.

2.3 Description of the fragments

The preservation state of the textiles recovered from BZN17 is exceptional by any archaeological standard. Organic materials such as silk and leather are particularly vulnerable to decay, and the survival of such an assemblage suggests that the wreck was rapidly buried in fine sediment with low microbial activity. These anaerobic conditions drastically slowed fiber degradation, a phenomenon

[7] Westera, "The Silk Dress and the Shipwreck."

[8] Ibid.

[9] Dickinson, "Drowned Books and Ghost Books.", Rudolph Matthee, "The Dutch East India Company and Asian Raw Silk: From Iran to Bengal via China and Vietnam," in *Threads of Global Desire: Silk in the Pre-Modern World*, ed. Dagmar Schäfer, Giorgio Riello, and Luca Molà (Suffolk: The Boydell Press, 2018), 75-101; Vera-Simone Schulz, "Entangled Identities: Textiles and the Art and Architecture of the Apennine Peninsula in a Trans-Mediterranean Perspective," in *The Hidden Life of Textiles in the Medieval and Early Modern Mediterranean: Contexts and Cross-Cultural Encounters in the Islamic, Latinate and Eastern Christian Worlds*, ed. Nikolaos Vryzidis (Turnhout: Brepols, 2020), 119-154.

[10] Dickinson, "Drowned Books and Ghost Books."; Archaeologische kroniek.

also observed in other Wadden Sea wrecks but rarely involving such fine materials.[11] Despite the positive preservation conditions, the textiles were subject to some deterioration caused by marine organisms, corrosion, and exposure to sulfides and other mineral accretions. Metal threads exhibited blackening and mineral crusts due to reactions with seawater. Microscopic analysis by Savelli (2018) revealed silver sulfide and iron sulfide deposits, as well as signs of pyrite formation on the fibers—a dangerous agent of post-recovery decay.[12]

The initial handling of the textiles by divers, while pragmatic, inadvertently introduced stress factors. Some textiles were rinsed with garden hoses or washed in domestic machines; others were dried in the sun. These actions, undertaken with the best intentions, deviated from common conservation practices. Furthermore, there was a severe lack of documentation, both of the archaeological context and site, as well as the actions after they were found, such as the manner of extraction, transport and cleaning. Objects were stored in stacked PVC crates without proper support or separation, likely contributing to some physical damage. [13]

Subsequent efforts by professionals focused on stabilizing the collection. Using light microscopy, pH analysis, and scanning electron microscopy (SEM), researchers assessed the microstructural stability of the silk and evaluated corrosion pathways in the metal threads. These studies confirmed the high technical quality of the threads, which were mostly made of gilded silver wound around silk or linen cores—typical of court dress and luxury items in the 17th century.[14]

Looking at the whole collection of the fragments that are the subject of this thesis (the "tent collection") , it is very likely, based on the materials, that they once formed part of the same object or set of objects. Almost all fragments have the same decoration of a more saturated true red trim around the edges, accompanied by frog fastenings (male and female[15]) and sometimes a fringe, of which there is a long and a short variety.

The two largest objects in the group – complete panels 6263-102 and 6263-104 – offer the most information about the likely structure and look of the original set. Fragment 6263-102 measures 172 cm in height and 200 cm in width and features eight female frog fastenings along each vertical side. It includes a narrow fringe along the bottom and both sides, bilateral symmetrical damage, and remnants of tape stitched at the top edge. Fragment 6263-104, slightly narrower (170 cm high, 190–200 cm wide), mirrors this layout with male frog fastenings and similar fringe and reinforcement features. However, it has been distorted into a bow-like shape due to the presence of an unknown substance, possible metal corrosion contaminations, which stuck the middle part of the fragment to itself. The substance is likely non-original material introduced post-deposition, during its time underwater.

Another significant fragment is 6263-051. It is currently a diamond shape, with all sides bearing evidence of having been torn from their surrounding fabric. It bears folds that indicate that it must have been folded in half lengthwise and again width wise, and as a result it displays mirrored damage on both sides, sustained while in its folded state. It measures approximately 70 cm in length and 36.5 cm in width and is double-layered, as two identically torn, but not connected silk fragments are stacked on top of each other.

Two fragments offer likely examples of corners. 6263-030 includes three male frog fastenings

[11] Van Bommel, et al., "Chemical Analysis."
[12] Savelli, *Metal Threads*.

[13] Kramer, *Diving into Details*.

[14] Savelli, *Metal Threads*.

[15] The terms male and female frogs are used here, what is meant by this is the following: male frogs are the buttons and female frogs are the loops.

and remnants of top-edge reinforcement tape, suggesting a top-left panel corner. 6333-51, by contrast, has a male frog along one side and fringe along both edges, indicating it may come from a left, lower corner.

Another grouping of fragments stands out: fragments 6263-052, -053, and -081, show two sides of panels sewn together, each with three sets of male and female frogs. These fastenings appear to be decorative rather than. They have wide fringes and a symmetrical construction.

Additional edge fragments with individual frogs include pieces like 6263-055, -056, -062, -070, and -073, among others. These are primarily single-frog segments with varying amounts of surrounding fabric and side-edge trim, evidence of there having been more material that may have belonged to other panels. Notably, 6263-071 contains a single female frog, with fringe and surrounding textile intact. This suggests, based on the distribution of the closures on the two complete panels with only a single type of closure per panel, that there would have been at least two more panels. Several fragments of other isolated frog fastenings without additional fabric or trim: three male frogs (6263-002, -066, -076) and eight female frogs (6261-015, -001, -063, -064, -065, -067, -068, -074). Contrary to the edges that have been sewn together, these remaining frogs — both with surrounding fabric and individual — could have served as functional closures along the vertical edges of panels.

Fragment ID	Features
6263-102	200 × 172 cm, 8 female frogs/side, fringe, reinforced top
6263-104	170 × 190–200 cm, 8 male frogs/side, fringe, reinforced top, bow-shaped
6263-051	70 × 36.5 cm, folded, mirrored damage, double-layered
6263-030	Top edge reinforcement, 3 male frogs on left side
6333-51	Male frog on left, fringe around edges
6263-052	Sewn edges, 3 sets of M+F frogs, wide fringe
6263-053	Sewn edges, 3 sets of M+F frogs, wide fringe
6263-081	Sewn edges, 3 sets of M+F frogs, wide fringe
6263-054	Fringe only, no frogs
6263-055 to -078	Single frogs (mostly male), partial fabric and edge trim
6263-097	Long strip of wide fringe, no frogs
6263-099	Male frog with longer side edge trim
6333-50	1 male + 1 female frog, sewn shut
Loose frogs (e.g., -002, -066, -076, -001, -063, etc.)	Isolated frogs, no attached fabric

The material analysis[16] of the BZN17 fragments (samples 6263-104 and 6263-102) has revealed significant insights into the dyestuffs and materials used in these 17th-century textiles. Transmitted light microscopy showed that the fragments are made of a thin, lightweight silk (see appendix 10.2). High-Performance Liquid Chromatography (HPLC) analysis identified a mixture of what appears to be American cochineal (Dactylopius coccus) and European kermes (Kermes vermilio) in both the 6263-104 and the 6263-102 sample. This is consistent with the findings of dye anslysis that has previously been performed on other objects in the BZN17 collection. The presence of both carminic acid and kermesic acid peaks, creates an unusual profile that is uncommon for typical cochineal species. This distinctive signature suggests the possible use of Armenian cochineal (Porphyrophora hamelii), which can exhibit this type of dual-peak pattern. These insect dyes produced the vivid and

[16] The dye analysis was done by dr. Ana Albano Serrano. See appendix 10.3 and 10.4 for process and results. Microscopy to determine the material was done by the author, see appendix 10.2.

rich red colour of the fragments. SEM-EDX revealed small peaks of alum, possibly from the mordanting of the fabric. The analysis also revealed the presence of ellagic acid in most samples, indicating the use of tannin-rich additives during the dyeing process. This finding is consistent with traditional dyeing practices where tannins, commonly sourced from oak galls, were added to compensate for weight loss during silk degumming, strengthen the fibres, and protect them from contamination in the dye bath. Importantly, oak galls were preferred for crimson cochineal dyeing because they did not adversely affect the final colour. [17]

The BZN17 shipwreck is an extraordinary case of textiles surviving and being remarkably well-preserved to the present day, offering valuable insights into 17th-century material culture and maritime trade networks. Analysis reveals that the group of fragments that this thesis encompasses have the same materials, construction techniques, and decorative elements, suggesting they once formed a coherent textile ensemble. However, their fragmented state poses fundamental challenges for understanding their original form and function. Traditional physical examination can reveal much about individual fragments but cannot safely demonstrate how these pieces functioned together as a complete object without risking damage. Thus, digital reconstruction seems the most appropriate methodological approach in this case, allowing non-invasive analysis while providing flexibility to test multiple hypothetical reconstructions informed by historical evidence and comparative analysis.

[17] Ana Serrano, Maarten van Bommel, and Ineke Joosten, "Crimson, Black, Silver and Gold in a Lavish 17th-century Finding off the Coast of Texel, North Holland," poster presentation, November 2019; Ana Serrano, René Lugtigheid, and Maarten R. van Bommel, "The Colors of a Lavish 17th-Century Finding off the Coast of Texel, North Holland," draft, unpublished, 3-4; Ana Serrano et al., "Investigation of Crimson-dyed Fibres for a New Approach on the Characterization of Cochineal and Kermes Dyes in Historical Textiles," *Analytica Chimica Acta* 897 (2015): 116-127.

3. Digital heritage approaches

Textile heritage objects, especially archaeological ones, are extremely valuable and usually fragile artifacts of the past. Due to their organic materials, they rarely survive completely and in the archaeological context they are usually fragmented, deformed and deteriorated. Furthermore, the nature of textile objects is in most cases utilitarian, making their deterioration almost unavoidable and part of their specific history. As such, they require extensive puzzling and research to even verify what object they may have belonged to. In most cases they are hard to read for experts and even more so for a general museum audience. [18]

When these already fragile objects are acquired by museums or heritage institutions, the next challenge is presented: what should be done with such important heritage? As these objects are so valuable, it is imperative to protect them for future generations, but also to make them accessible for educational and research purposes. Oftentimes, their caretakers decide that these fragile objects are better off protected in storage than on display. Exhibiting them carries many more risks as ideal conditions are harder to maintain. However, even when the utmost care is taken and some objects might be in good enough condition to last a couple more decades, the aging of textiles can only be slowed down, but never prevented.[19]

And this is where reconstruction comes into play, specifically digital reconstruction. Making replicas is a practice occasionally used in the field of textile conservation, as a way of improving the understanding of an object. However, making physical reconstructions, while teaching valuable lessons in craftsmanship, is a cumbersome process. Over the last years, virtual replication has come into fashion, and has given the reconstruction of textile objects a new boost. Digital techniques offer flexible and intuitive solutions, and allow for effective preservation and dissemination. Just like traditional reconstruction practices they help telling the artifacts story without severely impacting possibly fragile textiles. Additionally, they reduce the need for handling the object even further, improve accessibility for various purposes, they do not entail having to store even more physical objects, they allow for more experimentation and hypotheses, and they are more environmentally friendly than physical reconstructions.[20]

In this chapter the use of digital reconstructions as a preservation and dissemination approach will be discussed. Digital visualisation techniques can serve as relatively quick and intuitive approaches in our increasingly digital age, and provide new opportunities for protecting and interacting with heritage textiles.[21]

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[18] Zain R. Fadillah et al., "Automatic Thread Counting for Archaeological Textiles [Abstract]," in *The Proceedings of 6th International Conference on Innovation in Art Research and Technology* (Oslo: University of Oslo, June 4-7, 2024), 189-190, 189; Chun Zhu et al., "Research on Archaeology and Digital Restoration of Costumes in DaoLian Painting," *Sustainability* 14 (2022): 14054, 1-3.

[19] Q.-K. Ding and H.-E. Liang, "Digital Restoration and Reconstruction of Heritage Clothing: A Review," *Heritage Science* 12, no. 225 (2024): 1-21,1; Geheng Feng et al., "Study and Digital Restoration of Costumes Unearthed from the Tomb of Zhao Boyun," *Fibres & Textiles in Eastern Europe* 31, no. 5 (2023): 56-65, 56 Andreja Rudolf et al., "Using Digital Technology for the Sustainable Preservation of Clothing Heritage: A Virtual Reconstruction of the 1848/49 Uniform," *Sustainability* 16, no. 7757 (2024), 2.

[20] Rudolf, et al., "Using Digital Technology for the Sustainable Preservation of Clothing Heritage," 2, 21-22; Ding, et al., "Digital Restoration and Reconstruction of Heritage Clothing", 1-21; Zhu et al., "Research on Archaeology and Digital Restoration of Costumes in DaoLian Painting," 1; Feng et al., "Study and Digital Restoration of Costumes Unearthed from the Tomb of Zhao Boyun," 56–65.

[21] Kaixuan Liu et al., "Archaeology and Virtual Simulation Restoration of Costumes in the Han Xizai Banquet Painting," *AUTEX Research Journal* 23, no. 2 (June 2023): 238-252, 238-239; C. Liu, R. Cui, and Z. Wang, "Digital Virtual Simulation

3.1 The value of digital reconstructions

Textiles will never stop ageing (at least not with the technology we currently have at our disposal) and are inherently fragile, often more so than other museum objects. And traditional conservation and restoration methods are usually quite invasive in addition to taking up a considerable amount of time and money. Creating physical replicas as part of conservation efforts can also be a costly and time-consuming endeavour, requiring specific materials and expert craftsmanship and a lot more physical labour. Digital conservation approaches avoid excess handling and making replicas using these techniques preserves the original for many years to come, while saving time and resources, as well as enables a wider audience to digitally interact with the object. [22]

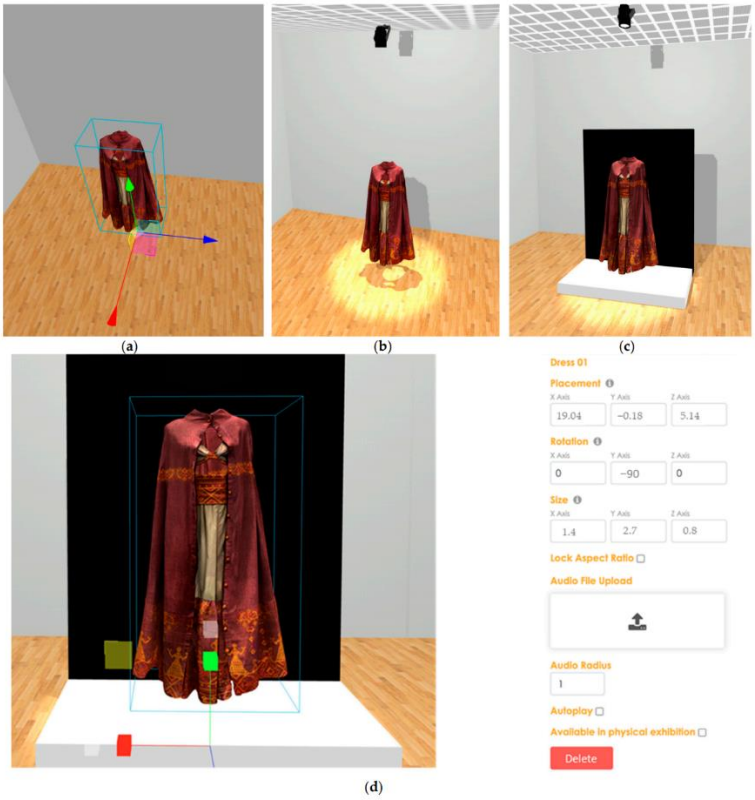

Figure 2 Example of a digital exhibition visualisation [reproduced from Xhako, et al. 2024].

Digital reconstructions are currently a popular tool for the non-invasive and future-proof preservation of heritage textiles. Digital visualisation offers new and extensive opportunities for the

for Cultural Clothing Restoration: Case Study of Tang Dynasty Mural 'Diplomatic Envoys' from Crown Prince Zhang Huai's Tomb," *Journal of Theoretical and Applied Electronic Commerce Research* 19 (2024): 1358-1391, 1358–1391, 1361.

[22] Adina Victoria Albu et al., "Digitalization of Garment in the Context of Circular Economy," *Industria Textila* 72, no. 1 (2021): 102-107, 103; G. Lo Cicero et al., "Recovering Sicilian Silk Heritage through Digital Technologies: The Case of Piraino's Collection," *Heritage* 5 (2022): 4245-4266, 4250; Kaixuan Liu et al., "Archaeology and Restoration of Costumes in Tang Tomb Murals Based on Reverse Engineering and Human-Computer Interaction Technology," *Sustainability* 14, no. 6232 (2022); Hanhan Wu et al., "Archaeological and Digital Restoration of Straight-front Robe of Mawangdui Han Dynasty Tomb Based on 3D Reverse Engineering and Man-machine Interactive Technologies," *Industria Textila* 73, no. 6 (2022): 635-644, 636; Rudolf, et al., "Using Digital Technology for the Sustainable Preservation of Clothing Heritage," 2; Melangell Penrhys and Michelle Barker, "A Dress Fit for a King," in *A Challenging Dimension: The Conservation and Research of Costume and Accessories, ICOM-CC Textiles Working Group Interim Meeting* (Abegg-Stiftung, Riggisberg, Switzerland, 2019); De Groot, Improving Understanding, 15, 22-24, 30-31, 60.

access to and interaction with heritage, in both research and display contexts. Digitization offers a more vivid, inexpensive and extremely informative approach to preserving and exhibiting objects. It allows for interaction, reproduction, more intensive educational approaches and online display or even entire virtual museums. Currently, many textile objects are semi-permanently in storage, with preservation in mind, but with digital replicas, visitors and other interested parties can interact with these objects regardless of their physical location. This would democratise a large part of current museum collections, as, at the moment, only a privileged few can observe and touch them.[23]

Digitalised heritage offers a unique opportunity to engage a new public with hands-on experiences, by awakening these so called "sleeping beauties". Virtual exhibitions, interactive museum displays and online spaces can help people interact with the objects in otherwise impossible ways and allow people to explore them from every angle and in great detail. In this way, heritage can be used and displayed in new contexts, such as by creatives in the cultural sector, improving understanding of historical objects outside the walls of the museum. Digitising heritage encourages a whole view on cultural preservation, as increasing accessibility to heritage improves understanding and underlines the importance of conservation.[24]

The properties that make digital reconstruction such a valuable tool in heritage protection are that they provide a detailed, interactive, manipulable model that allows all sorts of interested parties to study construction, material properties and other physical elements. They show, through the interaction inherent in the digital medium, details that normally might remain hidden when an object is on display. Research is encouraged through the use of models, as a more intensive way of handling the objects is possible in their digital version. Additionally, making a reconstruction often requires collaboration with experts from different fields, and this interdisciplinary approach is considered highly beneficial in our current age of heritage thinking. It entails approaching heritage at multiple levels, such as material, data, construction and background, providing a deep understanding of the object.[25]

Another powerful possibility of digital heritage is the testing of hypotheses, as multiple reconstructions can be made to see which fit the particular object and its context best. Often, historical sources, such as texts, paintings or patterns, allow for multiple interpretations and these would be

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[23] Liu, et al., "Digital Virtual Simulation for Cultural Clothing Restoration," 1358-59; Rudolf, et al., "Using Digital Technology for the Sustainable Preservation of Clothing Heritage," 2 Kaixuan Liu, Jiayu Zhao, and Chun Zhu, "Research on Digital Restoration of Plain Unlined Silk Gauze Gown of Mawangdui Han Dynasty Tomb Based on AHP and Human-Computer Interaction Technology," *Sustainability* 14, no. 14 (2022): 8713, 16; Liu et al., "Archaeology and Virtual Simulation Restoration of Costumes in the Han Xizai Banquet Painting," 239; Albu et al., "Digitalization of Garment in the Context of Circular Economy," 103; Aleksei Moskvin, Victor Kuzmichev, and Mariia Moskvina, "Digital Replicas of Historical Skirts," *The Journal of The Textile Institute* 110, no. 12 (2019): 1810-1826, 1810.

[24] d_archive, "3D Replicas and Preservation," October 27, 2023, accessed April 1, 2025, https://darchive.io/blog/3d-replicas-preservation/.; d_archive, "About d_archive and Digital Craftsmanship," September 21, 2023, accessed April 1, 2025, https://darchive.io/blog/why-d_archive-and-digital-craftsmanship/.; Zhu et al., "Research on Archaeology and Digital Restoration of Costumes in DaoLian Painting," 9; A. Xhako et al., "Reviving Antiquity in the Digital Era: Digitization, Semantic Curation, and VR Exhibition of Contemporary Dresses," *Computers* 13, no. 57 (2024): 1-22,1-2; Liu et al., "Archaeology and Virtual Simulation Restoration of Costumes in the Han Xizai Banquet Painting," 239; Felicity A. McDowall, "Lost in Temporal Translation: A Visual and Visitor-based Evaluation of Pre-history Displays," *Antiquity* 97, no. 393 (2023): 707-725, 721.

[25] d_archive, "3D replicas and preservation"; Dries Debackere, "(Un)constructed, Reconstructed, and Deconstructed Again. An Examination of the Context, Reconstruction and Display Possibilities of Five Lace Panels for Use on a Gown, ca. 1900-10, at the MoMu Fashion Museum in Antwerp" (2024), 1-35; Martijn A. Wijnhoven and Aleksei Moskvin, "Digital Replication and Reconstruction of Mail Armour," *Journal of Cultural Heritage* 45 (2020): 221-233; Liu et al., "Archaeology and Virtual Simulation Restoration of Costumes in the Han Xizai Banquet Painting," 249; Jane Malcolm-Davies, "Structuring Reconstructions: Recognising the Advantages of Interdisciplinary Data in Methodical Research," *Heritage Science* 11, no. 182 (2023), 1, 10; Liu, et al., "Digital Virtual Simulation for Cultural Clothing Restoration," 1361.

impossible to test all using traditional methods of physical reconstruction. Furthermore, these digital methods facilitate comparative analysis of objects that may never physically be in the same room, providing new opportunities for research. This testing and comparative analysis undoubtedly contributes to a new understanding of textile heritage, akin to performing heritage and art technological research. Digital heritage can open doors with regards to understanding the object's physical aspects, as well as its intangible social, economic, cultural and historical contexts.[26]

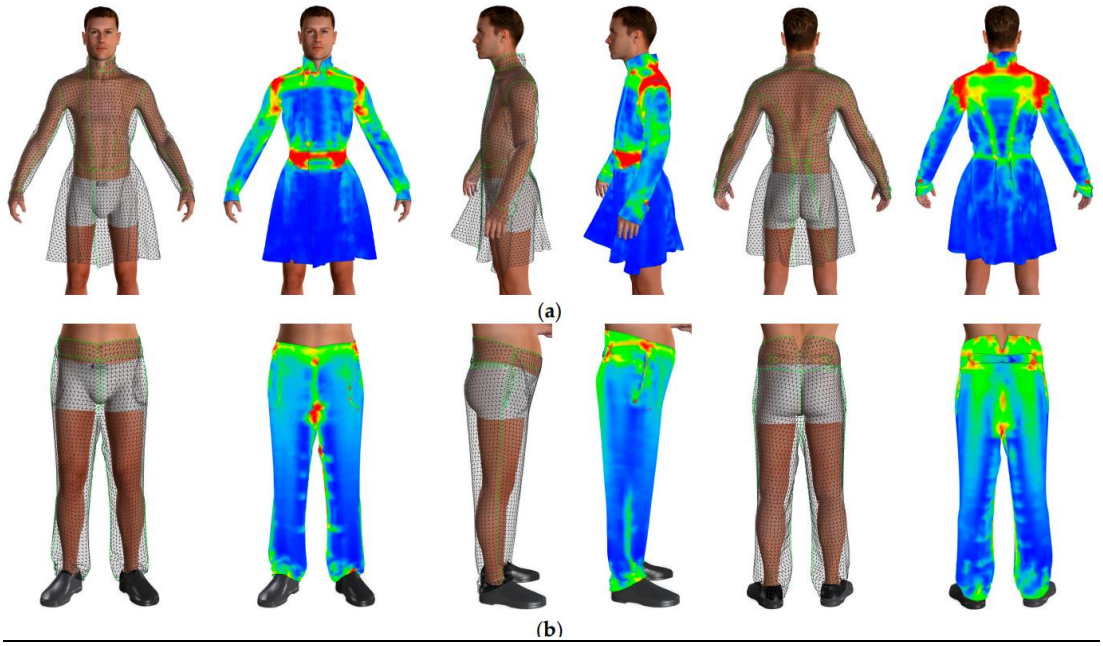

Figure 3 Visualising the different types of tension and gaping of fabric through 3D modelling [reproduced from Rudolf, et al., 2024).

3.2 Current uses of digital reconstructions in textile heritage

Over the last years, more and more museums have included at least some form of digital heritage presentation in their exhibition strategies. These institutions charged with the dissemination of heritage to as wide an audience as possible have seen the positive effects virtual approaches have on visitor engagement. Be it with websites, online exhibitions, interactive displays, or complete experiences, many museums have expanded their reach beyond the physical boundaries of the object itself. All these approaches, such as *virtual reality* (VR) and *augmented reality* (AR) have led to more meaningful and deep experiences, as the user becomes actively involved, instead of being a passive observer as is traditionally the case in many museums. Viewers are able to observe details of the textile they would not have been able to see on traditional display, and objects that do not speak to the imagination, such as archaeological textile fragments, are transformed through reconstruction. Digital approaches make the objects come alive once again and can help promote understanding of their context and appreciation of the craftsmanship that went into them.[27]

[26] Fadillah et al., "Automatic Thread Counting for Archaeological Textiles," , 189; Ding, et al., "Digital Restoration and Reconstruction of Heritage Clothing," 636; Liu et al., "Archaeology and Virtual Simulation Restoration of Costumes in the Han Xizai Banquet Painting," 239; d_archive, "3D replicas and preservation".

[27]Xhako et al., "Reviving Antiquity in the Digital Era," 3; Liu et al., "Archaeology and Virtual Simulation Restoration of Costumes in the Han Xizai Banquet Painting," 246; Nuno Martins and Daniel Brandão, eds., *Advances in Design and Digital Communication IV: Proceedings of the 7th International Conference on Design and Digital Communication, Digicom 2023,*

Digitalizing textile heritage objects also has unmistakable advantages for the conservation of these objects, as mentioned before. By making simulations based on object and material types, conservators might be able to predict the degradation of the textile and provide fitting treatment approaches. Trials through digital restoration might also be helpful in testing different treatments, while reducing the risks associated with excessive handling. It also negates the heated ethical debates on the necessity of physical restorations for the purpose of readability and aesthetics, and protects the integrity of the original material. It can enable conservators to go even further in some cases, as lost elements can be fully reconstructed and added to the object more quickly and without subjecting the object to some irreversible treatment. Thus, it enables the preservation of fragile textiles for the future, without having to worry as much about the evolution of conservation science and technology and changes in ethical debates.[28]

And as cherry on top, digitalizing historical and heritage textiles allows for a unique opportunity to revitalize their specific textile culture. The models can be spread and reused freely, as references or for reproduction, in areas such as the fashion industry, and in media such as film, games and other art forms. They can also revive lost practices and renew interest in traditional textile production. By sharing these objects according to heritage standards such as open data infrastructures and the FAIR principles, the heritage is democratized. This paints a hopeful picture for the future of heritage and incentivises their protection for ages to come.[29]

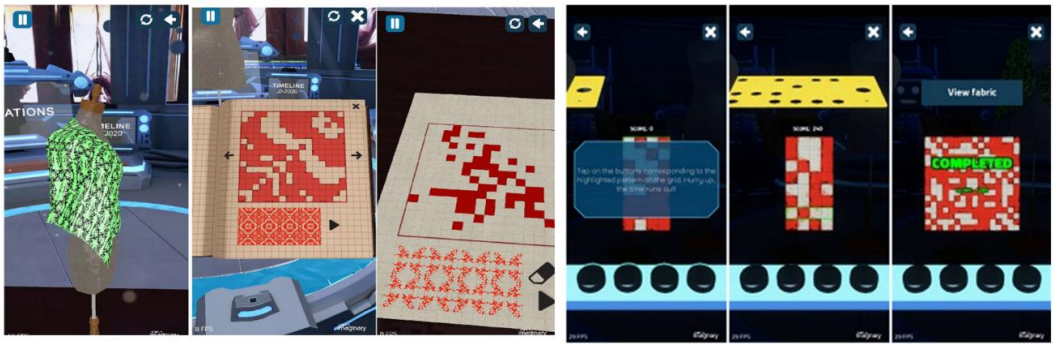

Figure 4. Craft games about reconstruction jacquard patterns [reproduced from Hauser, et al., 2022].

November 9-11, 2023, Barcelos, Portugal (Springer, 2023); Tiantian Tang et al., "The Impact of Museum Exhibition Experience Service and Virtual Simulation Technology on the Conservation of Textile Cultural Relics," *Mediterranean Archaeology and Archaeometry* 24, no. 3 (2024): 271-284, 272; Xhako et al., "Reviving Antiquity in the Digital Era," 3; Zhu et al., "Research on Archaeology and Digital Restoration of Costumes in DaoLian Painting," 9; H. Hauser et al., "Multimodal Narratives for the Presentation of Silk Heritage in the Museum," *Heritage* 5 (2022): 461-487, 463-4; McDowall, "Lost in temporal translation," 721; d_archive, "about d_archive and digital craftsmanship".

[28] Tiantian, et al., "The Impact of Museum Exhibition Experience Service and Virtual Simulation Technology,"271–284; Liu et al., "Archaeology and Restoration of Costumes in Tang Tomb Murals Albu et al., "Digitalization of Garment in the Context of Circular Economy," 104; Rudolf, et al., "Using Digital Technology for the Sustainable Preservation of Clothing Heritage," 2.

[29] Xhako, et al., "Reviving Antiquity in the Digital Era," 13, 57. Wu, et al. , Archaeological and digital restoration of straight-front robe, 642; Liu et al., "Archaeology and Virtual Simulation Restoration of Costumes in the Han Xizai Banquet Painting," 239; Wijnhoven, et al., "Digital Replication and Reconstruction of Mail Armour," 221; Feng, et al., "Study and Digital Restoration of Costumes Unearthed from the Tomb of Zhao Boyun", 56–65; Aleksei Moskvin, Victor Kuzmichev, and Mariia Moskvina, "Digital Replicas of Historical Skirts," *The Journal of The Textile Institute* 110, no. 12 (2019): 1810-1826.

3.4 Critically considering heritage digitisation

Implementing all these promising approaches does ask for critical consideration by heritage professionals. To make sure these projects have a strong scientific basis, guidelines and systematic approaches have to be developed. For instance, the interdisciplinarity of digital heritage is one of its strong suits, but it also entails the merging of many different standards from all disciplines involved. Combining these types of research, analysis and craft expertise input requires the utmost care, to have a clear understanding of used definitions, handling of sources and the accessibility and findability of information and data.[30]

In addition, there are some ethical and practical considerations that come with this new field. Take for instance, the aura of authenticity, museum visitors may see a reconstruction and assume this must be the truth. Thereby foregoing the fact that many valid hypotheses might exist alongside one another, but that there is usually only one that is displayed. Oftentimes, due to the scarcity of complete textile finds, reconstructions are based on incomplete evidence. It is important to clearly explain this multiplicity to a non-expert audience. Alongside this idea of authenticity, is a concept that should guide the goals of heritage reconstruction: accuracy. This meant that all reconstruction should be accompanied by the proper documentation of the reconstruction process, aims and validation. And this information should always be open to the public along with the model in accordance with the FAIR principles.[31]

Digitalisation of cultural heritage brings positive developments in the area of sustainability in the heritage sector. The production of physical replicas is inherently wasteful, and even though storing all these digital models takes energy and space in data-servers, they are far less dependent on exhaustible resources. They provide an opportunity to significantly diminish the carbon footprint of museums and other institutions that put on exhibitions, as they lessen the need for travel and the use of physical materials and all their associated waste. Digital heritage is a new step on the way to a future of sustainable heritage management.[32]

Despite such an obvious advantage, there are some serious constraints to introducing digital visualisation techniques sectorwide. In the long run they might prove less costly than traditional approaches, however, instating them does initially require quite some money and effort. Most heritage professionals do not have a strong background in digital techniques, and making connections with the right people or educating new personnel is not always simple. Textiles remain a complex object type, and these reconstructions require a vast array of knowledge, from handling different types of sources, to technical understanding of the craft and data management. And when such a project is successfully rolled out, it does not necessarily become accessible to a wider audience right away. And even then, if the interfaces of these digitalised collections are not user friendly or conducive to enabling easy dissemination, non-experts are once again excluded from the educational and social potential of this type of heritage preservation.[33]

The academic discourse surrounding digital reconstructions in textile heritage illustrates that the

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[30] Ding, et al., “Digital restoration and reconstruction of heritage clothing,” 16; Tang, et al., "The Impact of Museum Exhibition Experience Service and Virtual Simulation,” 271–284, 2; Malcolm-Davies, "Structuring Reconstructions, ”1-5.

[31] ICOMOS, *The Seville Principles: International Principles of Virtual Archaeology* (19th ICOMOS General Assembly, New Delhi, 2017; Hugh Denard, ed., *The London Charter for the Computer-Based Visualisation of Cultural Heritage*, Version 2.1 (King's College London, 2009), 189;

[32] Rudolf, et al., "Using Digital Technology for the Sustainable Preservation of Clothing Heritage,”1-22;

[33] Cicero, et al., “Recovering Sicilian Silk Heritage through Digital Technologies”, 4247; Iñigo Leon, José Javier Pérez, and María Senderos, "Advanced Techniques for Fast and Accurate Heritage Digitisation in Multiple Case Studies," *Sustainability* 12, no. 156068 (2020), 2.

heritage field has entered a phase of dynamic transition, where technological innovation meets traditional conservation practices. Digital reconstruction proves to be a powerful solution to the inherent fragility of textile objects, offering non-invasive preservation methods that extend accessibility beyond the physical constraints of museums. The potential for digital heritage to democratize access to textile collections, support sustainable conservation practices, and revitalize traditional craft knowledge, makes it as essential tool for future heritage preservation. Having established the theoretical foundation and identified the key opportunities and challenges within this emerging field, the next chapter examines the specific techniques and methodologies involved in digital textile heritage projects.

4. Digital visualisation techniques

The reconstruction of fragmented textiles into their original forms represents a complex challenge that has increasingly been met with innovative digital visualisation techniques. These methods, rooted in the broader field of digital humanities, have transformed the study, preservation, and dissemination of cultural heritage, particularly for fragile artefacts like textiles. Over the past two decades, advances in digital visualisation and replication methods have fundamentally transformed the ways in which scholars analyse, interpret, and disseminate textile artefacts, at the intersection of cultural heritage, computer science, and material studies. This chapter explores the state of the art in digital visualisation techniques as they apply to reconstructing the original object from a group of archaeological textile fragments. It is divided into four key sections: Digital Techniques for Cultural Heritage, Imaging Techniques, Computational Techniques, and Modelling. Each section reviews current academic discourse, drawing on established methodologies, ethical frameworks, and technological advancements to inform the approach of this thesis. The application of digital techniques in textile research and conservation is extremely diverse, with methodologies tailored to the specific needs of each project. Throughout the chapter, case studies will serve as illustrations of how varied digital visualisation approaches have supported conservators, textile designers, and scholars by enabling preservation, analysis, and creative engagement, often without requiring direct handling of fragile originals.

4.1 Digital techniques for cultural heritage

The integration of digital visualisation into cultural heritage studies has grown significantly in recent decades, offering new methods for analysing and reconstructing artefacts such as archaeological textiles. This growth is driven by the need to preserve fragile objects while making them accessible to scholars and the public alike. However, the application of these techniques is cannot happen within an academical framework without proper justification, necessitating a set of clear guidelines and best practices to ensure intellectual integrity and responsible practice.

Ethical frameworks such as the London Charter (2006) and the Seville Principles (2011) provide a foundation and guidelines for digital heritage projects. The London Charter emphasises the importance of intellectual and technical precision and transparency in computer-based visualisation, advocating for transparency in documenting research sources and methods to maintain scholarly credibility. Principle 3 of the Charter specifically calls for structured documentation of all sources influencing visualisation decisions. This includes structured metadata, clear records of fragment provenance, and explicit documentation of all manipulations and hypotheses tested in virtual environments. Building on this, the Seville Principles extend these standards to archaeological contexts, promoting interdisciplinarity, historical accuracy, and scientific transparency. Additionally, the FAIR principles (Findable, Accessible, Interoperable, Reusable) have been developed for these types of approaches, ensuring that digital heritage data remains open and usable for future research and a wider public. This also contributes to another academic standard that digital heritage projects are not exempted from: it is essential for good scientific research to document both the technical process, sources and the interpretative decisions, by using systematic and clear metadata that enable other researchers to retrace, review and duplicate said process. These guidelines collectively underscore the need for clear aims, methods, and logical processes in digital reconstructions. [34]

[34] Marco Limoncelli, "The London Charter: A Guide for the Digital Representation of Cultural Heritage," in *Digital Restoration and Virtual Reconstructions: Methodological Issues and Case Studies*, ed. E. Trisio, E. Demetrescu, and D. Ferdani (Digital Heritage, 2023), 19-28**.** ICOMOS, *The Seville Principles;* Denard, ed., *The London Charter*; Limoncelli,

The advantages of digital visualisation and imaging techniques for heritage textiles are quite extensive and diverse. First, they enable enhanced analysis and interpretation of details such as weave patters, thread counts and degradation. Digital microscopy and advanced photography, for instance, allow for non-invasive examination of fragile fragments. Second, these methods support preservation by minimising physical handling, with (ultra-high-resolution) images serving as primary data for virtual manipulation. A good example of the possibilities for this approach is the conservation of the Shigiory Torbinata, at the Bonnefantenmuseum. Through digital pattern reconstruction using high-resolution photography and polarizing filters, lost or damaged patterns of a Ferdi Tajiri sculpture were digitally recreated before applying them to fabric that could be used as a replacement. This iterative, non-invasive approach reduced guesswork and protected the integrity of the original textile during restoration. Third, digital tools enable the visualisation of reconstruction hypotheses, enabling researchers to test multiple arrangements of fragments and compare them against historical evidence. For example, without any surviving garments from the period, researchers used 3D digital fitting and archaeological evidence to recreate costumes from the Han Xizai Banquet painting virtually. Integrating virtual sewing and pattern reconstruction preserved intangible cultural heritage, supported educational initiatives, and allowed digital reuse in media and museums, without relying on speculative physical reproductions. This leads to the fourth advantage of digital visualisation techniques; they improve communication and dissemination through interactive 3D models, augmented reality (AR), and virtual reality (VR) environments, fostering broader engagement with cultural heritage. For instance, the "Virtual Loom" software and ADASilk digital catalogue allowed small museums to digitally restore silk textiles at yarn-level detail. Semantic search tools and user-oriented design were developed for textile designers and researchers to retrieve, study, and reinterpret heritage patterns, supporting education, creativity, and preservation via accessible web platforms. Another similar approach was that of a project around a Mawangdui silk gauze gown: A delicate Han Dynasty silk gown that was too fragile for frequent handling or display, was reconstructed digitally using a 3D–2D–3D workflow, incorporating pattern flattening and virtual simulation. Evaluation via the Fuzzy Analytic Hierarchy Process ensured a scientifically robust and reproducible model, which contributed to interactive museum displays and increased public engagement with ancient garments. And finally, digital platforms support collaborative research by connecting interdisciplinary teams across institutions.In one instance, researchers developed a digital archive and used AI (LoRA model) to preserve endangered traditional patterns of Blue Clamp-resist dyeing to generate new, culturally inspired designs. This fusion of heritage and innovation supported sustainability and enabled creative reuse by designers.[35]

"The London Charter," 19-28; Marcello Canciani, "Digital Heritage: Before, During and After COVID-19: The Aurelian Walls of Rome," in *Digital Restoration and Virtual Reconstructions*, 95-102; M. Hostettler et al., "Concluding Remarks – Coordinates for the Future of Digitalised Archaeology," in *The 3 Dimensions of Digitalised Archaeology*, ed. M. Hostettler et al. (Springer, 2024), 217-223.

[35] Ana Serrano, Suzan Meijer, Rick R. van Rijn, Sophia Bethany Coban, Birgit Reissland, Erma Hermens, Kees Joost Batenburg, Maarten van Bommel,"A non-invasive imaging approach for improved assessments on the construction and the condition of historical knotted-pile carpets", *Journal of Cultural Heritage* 47, 2021, pp 79-88; 4DRL report series 6 Shigiory Torbinata Bonnefantenmuseum (p. 14); ARCHAEOLOGY AND VIRTUAL SIMULATION RESTORATION OF COSTUMES IN.pdf (pp. 1–2, 12–14)
Digital Human Modeling and Applications.pdf (pp. 121, 137–138); Portalés et al., Interactive Tools for the Preservation, Dissemination and Study of Silk Heritage (pp. 1–9);
Recovering Sicilian Silk Heritage... (pp. 1–4, 6–8, 11–15, 18–20); Wang, Y.; Zhou, Y. Artificial Intelligence-Driven Interactive Experience for Intangible Cultural Heritage: Sustainable Innovation of Blue Clamp-Resist Dyeing. Sustainability 2025, 17, 898.pp. 3, 6–7, 15–16; 5.C. F. Gulbrandsen, Reconstructing the Original Machine Learning Puzzle Assembly for Matching Archaeological Textile Fragments (Master's thesis, Norwegian University of Science and Technology, 2023); T. Iversen, Software for Virtual Puzzle Reassembly (Master's thesis, NTNU Open, 2024); J. M. A. Ali and H. M. Hamed, "Employing Augmented Reality for Reviving Heritage Sites: An AR Vision for Qasr al-Abd in Jordan," American Journal of Tourism Research 8, no. 1 (2019): 1-10.; L. F. Marques et al., "Cultural Heritage 3D Modelling and Visualisation within an Augmented Reality Environment," ACE: Arquitectura, Ciudad y Entorno (2017); D. Gigilashvili, H. Lukesova, and J. Y.

Past and current virtual heritage projects provide valuable examples. The TexRec Project, focused on the Oseberg ship burial textiles, exemplifies the use of ultra-high-resolution imaging and software for virtual reassembly of fragmented artefacts. Other initiatives, such as those integrating photogrammetry and laser scanning for 3D/4D preservation, offer methodological insights adaptable to textile reconstruction. These projects highlight the potential of digital tools to address the challenges of fragmented heritage, a foundation this thesis builds upon. And although AI is being used more frequently as a tool, all projects currently being undertaken can still be defined as processes in which digital techniques act as aids, without full automation. Human experts remain central to supply the correct input and validating of the results.[36]

4.2 Imaging techniques and methods

Capturing high-quality data is the first step in digitally visualising archaeological textile fragments. Various imaging techniques have been used in the digital heritage field, roughly since the 1990s, and a few of them will be discussed, out of the wide variety that exist. Finally the most useful techniques for this project will be explored. [37]

Previously used techniques include structured light and laser scanning, X-ray imaging, and computed tomography (CT). Laser and structured light scanning, both non-contact methods, generate precise 3D point clouds of an object's surface, offering high geometric accuracy for cultural heritage documentation. However, it often requires supplementary photography to capture texture and colour. X-ray imaging penetrates opaque materials, revealing internal structures and details obscured by surface damage, folds or other factors that might prevent analysis from naked-eye observation . CT scanning, an advanced X-ray technique, produces detailed 3D volume datasets, enabling non-destructive analysis of internal composition. These methods have proven effective in heritage contexts, from pottery digitisation to site preservation, but their application to textiles varies in complexity and cost.[38]

Hardeberg, "Criteria for Matching Fragmented Archaeological Textiles: A Survey," Archaeological Textiles Review, no. 66 (2023): 65-71.

[36] Iversen, Software for Virtual Puzzle Reassembly; A. T. Hassan and D. Fritsch, "Integration of Laser Scanning and Photogrammetry in 3D/4D Cultural Heritage Preservation–A Review," International Journal of Applied 9, no. 4 (2019): 16;

[37] Current Digital Archaeology Colleen Morgan, 214-215

[38] V. Parfenov et al., "Use of 3D Laser Scanning and Additive Technologies for Reconstruction of Damaged and Destroyed Cultural Heritage Objects," Quantum Beam Science 6, no. 1 (2022): 11.; Montusiewicz et al. 2021; Jitte Waagen and Tijm Lanjouw, Dresses from the 17th c. Palmhout shipwreck (2018 – 2021) https://4dresearchlab.nl/projects/palmout-shipwreck-dresses/ ; E. Trinkl et al., "Cross-Modal Search and Exploration of Greek Painted Pottery," in The 3 Dimensions of Digitalised Archaeology, 109-125; N. A. Haddad, L. A. Fakhoury, and Y. M. Sakr, "A Critical Anthology of International Charters, Conventions & Principles on Documentation of Cultural Heritage," Mediterranean Archaeology and Archaeometry 21 (2021): 291-310; Trinkl et al., "Cross-Modal Search and Exploration," 109-125.

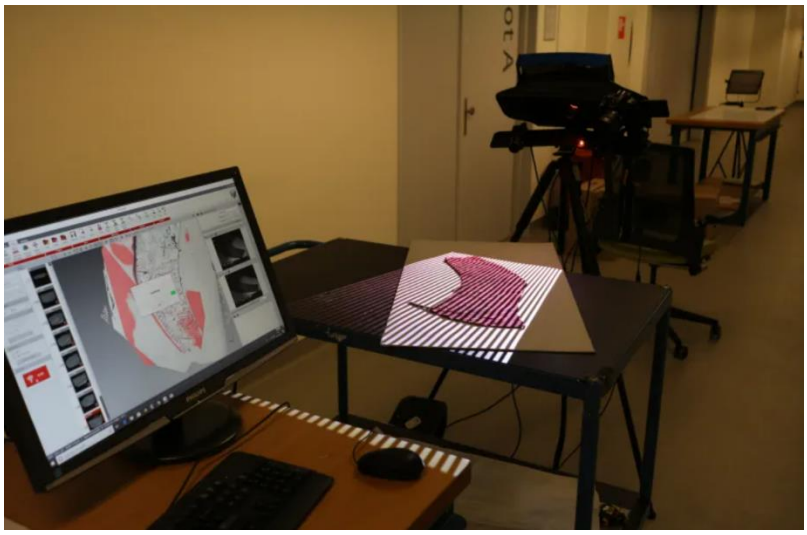

Figure 5 Structured light scan of textile from BZN17 in the depot of the Huis van Hilde [reproduced from Jitte Waagen and Tijm Lanjouw, 2018-2021].

3D scanning, photogrammetry, and non-invasive analysis were used for the digitisation and accurate reproduction of a deteriorated 19th-century Maribor National Guard uniform. Through 3D prototyping with OptiTex, researchers created visual and structural replicas for display and study, avoiding destructive sampling and promoting sustainable reproduction practices. Structured-light scanning, photogrammetry, and even motion capture can also be used to virtual museum environments, such as the Drexel Digital Museum Project and Spanish historical clothing archives. These platforms increased access to fragile objects, enhanced interactivity, and promoted research and design through immersive VR/AR experiences.[39]

For this project, photogrammetry and Gaussian Splatting are the used imaging techniques. As the fragments are numerous, extremely variable in size, and they cannot be transported, techniques such as X-ray and CT are not viable. They are also relatively flat and in good condition, so these techniques would not be contributing to a lot of new information. And while laser scanning would be a good option for three-dimensional objects, these objects are relatively flat. Photogrammetry reconstructs 3D geometry from overlapping photographs taken from multiple angles, using software like Agisoft Metashape to generate textured 3D models. Its cost-effectiveness, versatility, and ability to capture both form and surface texture make it ideal for fragile textile fragments. For this project, it also seemed like the technique that required the least expertise and the basics can be self-taught relatively easily, as a camera is a familiar tool and the application of modelling software required is quite intuitive. Advances in high-resolution handheld cameras have further democratised this technique. Gaussian Splatting is a newer rendering method, that uses 3D Gaussians to represent scenes, offering high-fidelity, real-time visualisation. Instead of relying on traditional polygonal meshes, each Gaussian contributes to the scene as a volumetric "splat," a data point that contains information about geometry, colour and texture, enabling an extremely accurate and lifelike representation of fine surface detail and lighting effects. Though not widely documented in textile studies, its potential for interactive exploration of spatial relationships among fragments aligns with this project's reconstructive aims. Photogrammetry served as the primary method of digitisation within this project due to its accessibility, and was used to make a dimensional, geometric model of the objects. Gaussian Splatting

[39] Using Digital Technology for the Sustainable Preservation of Clothing Heritage: A Virtual Reconstruction of the 1848/49 Uniform, Andreja Rudolf, Barbara Pu˘cko , Maja Hren Brvar and Katarina Remic, pp. 2–5, 8, 14–15, 21–22; s40691-022-00300-0.pdf, 2, 4–5, 17, 20–21; sustainability-15-09803-v4.pdf, 1–2, 9, 13–15.

was explored as a complementary tool for enhanced visualisation, as it does not make an actual model with physical geometry, but does offer a spatial, interactive rendering, that retains a higher degree of visual fidelity and detail than photogrammetry usually does, especially for textiles. While it is still and up and coming technique and has not been applied in textile or heritage studies, its strengths align closely with the challenges of digitalizing archaeological textiles, particularly in terms of capturing subtle material textures and spatial relationships.[40][41]

Figure 6 Virtual rendering of a reconstructed pattern on a scanned Ferdi Tajiri sculpture [reproduced from Walsh et al., 2024].

A crucial thing to note is that for all digital techniques it is extremely important to keep checking that the process is one of controlled, standardized image acquisition. Consistent lighting, scale, and calibration (such as use of colour checkers and reference targets) are vital to make sure a dataset is usable for computational analysis.[42]

[40] D. Ferdani, G. Bitelli, and F. Apollonio, "3D Modelling in Field Archaeology: Open Questions and Future Challenges," Virtual Archaeology Review 11, no. 22 (2020): 1-11.; M. Hostettler et al., "Digital Archaeology Between Hype and Reality," in The 3 Dimensions of Digitalised Archaeology, 181-204. E. Bozia, "'Please, Touch the Exhibits': 3D Archaeology for Experiential Spatialisation," in Capturing the Senses: Digital Methods for Sensory Archaeologies, ed. G. Landeschi and E. Betts (Springer, 2023), 127-143.

[41] Note: Gaussian Splatting is not explicitly cited in the provided sources; its inclusion is based on emerging trends in 3D rendering literature. https://www.youtube.com/watch?v=ERuRMOVO58Q

[42] Gulbrandsen, Reconstructing the Original Machine Learning Puzzle Assembly , 61.

4.3 Computational techniques

Once digitised, computational techniques are essential for analysing and reassembling textile fragments. These methods automate labour-intensive tasks, cluster related pieces, and assist in solving the reconstruction puzzle.

Computer-aided thread pattern analysis is a promising application of digital techniques employing a from of artificial intelligence, that can be used for the purposes of textile reconstruction. AI-assisted reconstruction methods, including pattern recognition algorithms, offer the potential to virtually "stitch" fragmented textiles back together, allowing conservators to test different reconstruction hypotheses. Conservators rely on criteria like thread count, yarn thickness, weave structure, twist/spin, selvedge, and visible motifs for matching fragments—features that used to not be captured well enough by generic image-processing algorithms – to puzzle fragments together. As digital techniques have evolved over the years, computers have also gotten better at recognising these elements. However, these programmes are still far from perfect and do require very specific conditions to work well, such as the textile needing to be completely flat. Current research is focusing on automating the measurement of these features from digital images, with the goal of developing textile-specific feature extractors that can mimic human expert analysis. Automatic thread counting algorithms, often applied to X-ray or high-resolution images, quantify warp and weft threads even in damaged areas. Weave analysis, supported by machine learning techniques like Convolutional Neural Networks (CNNs), identifies interlacing patterns and weave structures, though it requires extensive training datasets. Motif recognition, using computer vision and deep learning, detects and compares decorative patterns across fragments to suggest potential joins. These automated processes enhance efficiency and accuracy, supplementing traditional expertise.[43]

Using ultra-high-resolution photography and machine learning for texture-based clustering, the Oseberg project digitally reconstructed highly fragmented tapestries without risking physical handling. Software named Artifact Assembly was developed, and facilitated semi-automated puzzle-solving, providing a repeatable, collaborative environment. These methods were mainly aimed at motif analysis and hypothesis testing.[44]

Clustering fragments reduces the complexity of reconstruction by grouping similar pieces. Feature extraction—combining colour, texture (e.g., Local Binary Patterns), and deep learning-derived features with manual measurements like thread count—feeds into clustering algorithms such as k-means or hierarchical clustering. Evaluating these algorithms against textile datasets ensures robust grouping, a critical step in narrowing the scope of the reassembly process.[45]

Puzzling fragments together is the ultimate computational challenge, akin to solving a 3D jigsaw puzzle. Existing algorithms, adapted from other domains, analyse edges and surface characteristics to propose matches, though textile degradation complicates full automation. A critical methodological issue is the lack of ground truth: for most archaeological textile puzzles, we do not know the “correct” solution, complicating both algorithm development and evaluation. Artificial

[43] Gigilashvili, Criteria for matching fragmented archaeological textiles, 12; Gulbrandsen, Reconstructing the Original Machine Learning Puzzle Assembly , 61, 100; Noble, et al., “An Exceptional Commission: Conservation History, Treatment and Painting Technique of Rembrandt’s Marten and Oopjen, 1634.” *Rijksmuseum Bulletin* 66 (2018) 309-343.; https://www.avrotros.nl/archive/de-vlag-van-willem-barentsz-historisch-bewijs-aflevering-3~9xen55m1/; https://npo.nl/start/serie/historisch-bewijs/seizoen-2/vlag-barentsz/afspelen ;

[44] Gulbrandsen, Reconstructing the Original, 9, 13–15, 23–28, 34, 39, 56–58, 66, 95–101, 105; Iversen, Software for Virtual Puzzle Reassembly, 25–26, 33–34, 88, 119, 127, 151, 165; Gigilashvili, Criteria for matching fragmented archaeological textiles, 66–73;Gigilashvili, Computational techniques for virtual reconstruction of fragmented archaeological textiles, 1–13; Gigilashvili, Texture-based clustering of archaeological textile images, 1–3.

[45] Gulbrandsen, Reconstructing the Original Machine Learning Puzzle Assembly.

datasets (by cutting up known textiles) are used for testing, but results must be interpreted with caution.[46]

4.4 Modelling

Modelling the original textile object combines the digitised fragments and contextual evidence into a comprehensive 3D representation, reflecting its structure, behaviour, and appearance. This section draws on previous projects, handbooks, and best practices to define an approach for this specific project.

Reconstructing a textile's 3D form from 2D images—processed via photogrammetry—requires addressing its inherent flexibility. An iterative 2D-3D workflow, used in prior garment reconstructions, involves assembling 2D patterns from fragments, draping them onto virtual mannequins, and refining the results. In this case a pattern cannot be made from the fragments directly, as they are so highly fragmented. As such, each fragment is visually inspected and documented, forming initial hypotheses about possible groupings based on technical and stylistic features. Historical analogues, such as surviving textiles or iconographic evidence, inform plausible shapes and construction techniques. Material properties (fiber type, weave density, etc.) and contextual data (find location, associated artifacts, chronology) are critical in constraining reconstructions. Where available, chemical and 3D geometry data can be integrated to refine models. The archaeological context—burial conditions, location or associated finds—further influences and informs the model, ensuring fidelity to the original object's function.[47]

Software selection is critical. Agisoft Metashape will generate accurate 3D fragment models from photogrammetric data, providing a foundation for assembly. Clo3D and Marvelous Designer, designed for fabric simulation, excel at modelling textile behaviour, allowing 2D patterns to be draped and adjusted in 3D. These tools are ideal for reconstructing garments or draped objects, simulating gravity and flexibility. General-purpose software like Blender can refine geometry and integrate contextual details, though their cloth simulation is less specialised. For this project, Metashape will handle initial modelling of the fragment photogrammetry models as they are in their current state. Then a 3D model of a reconstruction, following a substantiated hypothesis on the original appearance, with Clo3D or Marvelous Designer reconstructing the overall structure and behaviour, followed by Blender for final presentation.[48]

[46] Gigilashvili, Computational techniques for virtual reconstruction of fragmented archaeological textiles,10-12; Gulbrandsen, Reconstructing the Original Machine Learning Puzzle Assembly for Matching Archaeological Textile Fragments, 96.
[47] Gigilashvili, Computational techniques for virtual reconstruction of fragmented archaeological textiles, 13.
[48] Note: Clo3D and Marvelous Designer are industry-standard tools for fabric simulation, not directly cited in the sources but widely recognised in textile modelling literature.

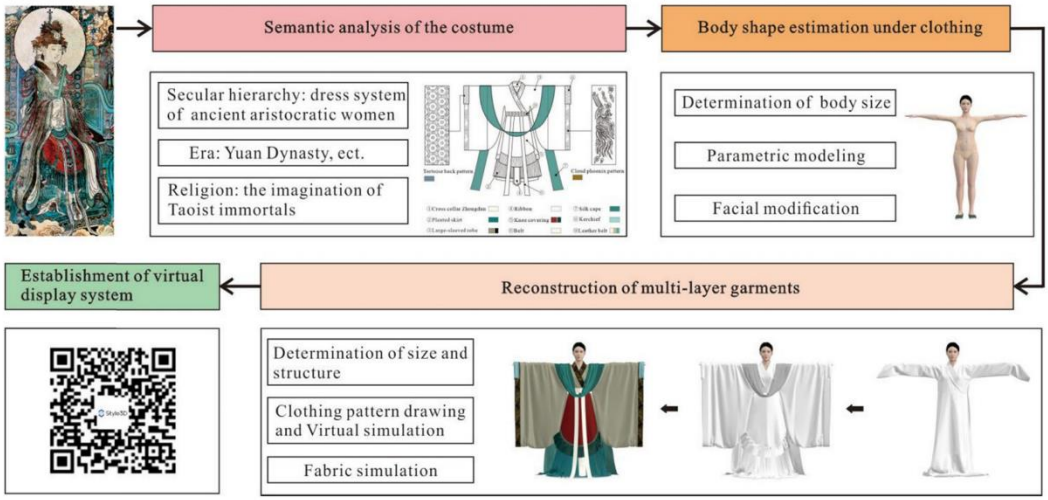

Figure 7 Illustration of garment reconstruction pipeline, from 2D image to 3D model [reproduced from Wang, et al., 2024].

This chapter has demonstrated that digital visualisation techniques have fundamentally transformed the study and preservation of textiles, offering non-invasive methods that enable detailed analysis while minimising physical handling of fragile artefacts. The review of current academic discourse reveals that advances in imaging techniques—from photogrammetry to emerging methods like Gaussian Splatting—offer increasingly sophisticated tools for capturing textile details. Computational techniques, including AI-assisted pattern recognition and clustering algorithms, show promise for automating labour-intensive reconstruction tasks, though human expertise remains central to validation and interpretation. The integration of these approaches into comprehensive 3D modelling workflows, enables researchers to test a variety of hypotheses. Building on this framework, this thesis employs photogrammetry and Gaussian Splatting as primary imaging techniques, combined with historical comparative research, to address the central question of what object the shipwreck textile fragments represent and how they would have appeared originally. The following chapter details the methodology and process of reconstructing the fragmented textiles.

5. The modelling process and preliminary study

5.1 Aims and justification

This chapter will discuss The fragments were documented and digitized using photogrammetry, facilitating future research and preserving the objects while minimising handling. Furthermore, by looking into the historical context and construction clues a hypothetical original state was modelled to show the potential for digital reconstruction methods for heritage textiles. Digital restoration allows researchers and conservators to gain more insight into the craftsmanship that went into creating the objects, as well as a closer understanding of the original intent of their maker. The reconstruction of a (possible) original state allows an object to once again tell its full story.

Archaeological textiles usually look very different from their original state, which is an obstacle for a non-expert museum audience. Reconstructions can in such cases be valuable tools in educating museum visitors, and can make severely damaged or deteriorated textiles accessible and relevant for the intended audience. At the Huis van Hilde, presenting a 'complete' image of an object creates a visible and interactive past that can inform visitors, young and old, of historical practices, craftsmanship and fashions.

To test an approach of visualising archaeological fragments in their original states and object context, using digital visualisation tools, a preliminary study was done that started before this thesis project, using a set of archaeological fragments that are also property of the Huis van Hilde. The reasoning behind this proof of concept is that many techniques used more frequently in other disciplines of cultural heritage may not work optimally for textiles. As such the methodology was tested on similar fragments from an archaeological context, also owned by the Huis van Hilde.[49]

5.2 Heiloo fragments: background of preliminary research

This preliminary study was done using a selection of embroidered fragments that are part of a larger group of archaeological textile fragments that have been established to make up a chasuble. The artefacts were found during an excavation at Het Witte Kerkje in Heiloo, North-Holland, in the 1960s. They were in possession of the UvA for a long time and were recently rediscovered there and the original owner, the Province of North-Holland, was notified of their discovery. Some of the fragments have been treated and returned to the Province, and are now kept in the depot of the Huis van Hilde, and the rest of the fragments still await treatment.

The silk velvet fragments were found as a bundle in a hole between seven- or eighteenth century graves. The bundle contained more objects made from different materials, such as metal, leather and even human hair. It was likely removed from a previously exhumed grave, and put back in good Christian practice. The bundle of fragments was wholly extracted from the excavation site, including the surrounding soil and kept in storage. This, in combination with their burial conditions, likely was the root cause of their heavily soiled, deformed and degraded current condition.[50]

The fragments that were used in this preliminary study were selected because they were already treated by a student conservator. Having been cleaned and flattened, their original shape and decoration of visible and able to be documented clearly. They are made of a dark silk velvet, likely in a red or burgundy colour, and embroidered with threads of silk and solid silver. There are remnants of a metal ribbon, or *galon*, along the edges. On several fragments the remains of embroideries are still

[49] Noa Duijsens, "Virtual Restoration of Heiloo Chasuble Fragments: Scientific Report on 3D visualization project" (2025).

[50] E. H. P. Cordfunke, De geschiedenis van het Witte Kerkje te Heiloo (Alkmaars Jaarboekje, 1966), 51-61; Matthew Hayes, Heiloo Fragments Treatment Report, 2024; H. Halbertsma, "Een onderzoek met de spade in het Witte Kerkje te Heiloo," in Alkmaars Jaarboek 1966, ed. P. J. Bosman et al. (1966), 62–67, 65.

visible, some more recognizable than others. For instance, there are multiple images of winged cherubs and there is evidence that other figures might have been a Madonna with Christ and two saints. Of the fragments that are considered in this proof of concept, 5 are hypothesized to have formed a cross as a decoration on a fiddle back chasuble. According to the style of the embroideries and other decorations, as well as the style of the chasuble, the textiles are likely 16th century, likely made in what was then the South of the Low Countries. [51]

Figure 8Chasuble fragments after treatment. Above: horizontal Madonna fragment, below: vertical fragments with cherubs and saints [reproduced from Hayes, 2024].

Medieval Catholic church edicts mandated that priests should wear liturgical garments, or *vestments*, that visualized the exaltation of the liturgy. These vestments were to be decorated with *orphreys*, vertical bands of luxurious materials which were often heavily embroidered. Usually the decoration is made up of figurative images, images of saint or a variety of scenes. These orphreys were often placed on chasubles and in the South of the Low Countries they were usually shaped like a Latin cross on the back and a vertical band on the front. From the second quarter of the 16th century, the Latin cross made

[51] Hayes, *Heiloo Fragments Conservation Treatment Report*; Halbertsma, "Een onderzoek met de spade in het Witte Kerkje te Heiloo.", 65.

its way to the North and replaced the forked cross (a vertical descending arm and upward tilted arms, resulting in a Y-shape, also known as a *gaffelkruis)* which used to be popular in that region.[52]

5.3 Research design

The aim of this research project is to gain better understanding of the (hypothetical) original appearance and purpose of a severely damaged and fragmented archaeological textile object. For both the Heiloo fragments and the BZN17 fragments a similar approach can be taken. Towards this goal, an approach combining virtual reconstruction and virtual restoration was chosen, by using photogrammetry and gaussian splatting to digitally analyse and preserve the fragments and using 3D modelling software (Blender for the Heiloo fragments and the BZN17 object), to reconstruct the original object based on measurements, material analysis and historical sources.

This approach seemed to be the most beneficial in these cases, as digital methods allow for the recreation of missing elements without impacting the fragile artifact too much. It provides a non-invasive way to restore and research the object and test hypotheses about its original appearance. This thesis aims to make this research accessible to both an expert and a non-expert audience, of researchers and Huis van Hilde visitors, wherein a clear, visual presentation of the research is crucial for engaging the audience.

As prescribed by the 4D Research Lab, this project uses a bottom-up methodology, by basing hypothesis on archival sources, art historical comparison and object-based research. This virtual reconstruction approach allows combining these sources into a coherent visual interpretation of incomplete or damaged heritage objects. Modern museum ethics also play a role in this case, as currently best practices are emphasizing preservation, minimal physical intervention and maximum accessibility. Digital visualisation techniques provide new possibilities to enhance visitor experience and engagement, improve conservation and preservation strategies and introduce a more inclusive and accessible approach to sharing and safeguarding cultural heritage.[53]

The reconstruction methodology is grounded in the London Charter and the Seville Principles, both of which advocate for transparency, intellectual rigor, and reproducibility in virtual heritage.[54] These charters emphasize documenting all interpretive decisions and maintaining interdisciplinary collaboration throughout the process. All reconstructions will be accompanied by annotations denoting the degree of certainty, ensuring clarity between data-derived results and hypothetical

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[52] H. L. M. Defoer, “Borduursels op laat-middeleeuwse kerkgewaden,” in Saskia de Bodt, et al. eds., Schilderen met gouddraad en zijde (Rijksmuseum Het Catharijneconvent, Utrecht, 1987) 51-82; D. O. R. Lugtigheid, Van aardse stof tot hemels lof: De transitie van de achttiende-eeuwse Noord-Nederlandse damesjapon van modeartikel tot kerkelijk gewaad in de katholieke eredienst (2021).

[53] Tijm Lanjouw and Jitte Waagen, 4D Research Lab Principles Statement v.1 (February 2020), accessed December 20, 2024, https://4dresearchlab.nl/3d-visualization/principles-and-visualisation-standards/4d-research-lab-principles-statem ent/.; Eva Pietroni and Daniele Ferdani, “Virtual Restoration and Virtual Reconstruction in Cultural Heritage: Terminology, Methodologies, Visual Representation Techniques and Cognitive Models,” Information 12, no. 4 (2021): 167, https://doi.org/10.3390/info12040167; Alaa Ababneh, “Digital Solutions for Cultural Heritage: Preservation, Interpretation, and Engagement in Line with the Venice Charter Principles,” in VIPERC2024: 3rd International Conference on Visual Pattern Extraction and Recognition for Cultural Heritage Understanding (Barcelona, September 1, 2024); *The Seville Principles: International Principles of Virtual Archaeology.* 19th ICOMOS General Assembly, New Delhi, 2017.

[54] Marco Limoncelli, “The London Charter: A Guide for the Digital Representation of Cultural Heritage,” in *Digital Restoration and Virtual Reconstructions*, ed. Trisio et al. (Springer, 2023), 19–28.

reconstructions.[55] Furthermore, the FAIR principles (Findable, Accessible, Interoperable, Reusable) will be applied to all digital data to facilitate future research and public engagement.[56]

Justification of the approach

This approach was tested and chosen based on the following factors:

- Limitations of 3D Scanning – Given the 2D nature and the deformation of the fragments, a 3D scan would not have provided an accurate reference for their original shape. Instead, photogrammetry using a 2D dataset, as well as a 2D reference image from the conservator's documentation, scaled using direct measurements, was used as a foundation for the 3D model.
- Need for Hypothetical Reconstruction – Because large sections of the original object are likely missing or damaged, reconstruction requires a comparative analysis of similar textiles from the same period. This allows for an informed recreation rather than a simple digital restoration of the existing fragments.
- Accessibility and Educational Goals – The final output is intended to serve both academic research and public engagement. Museums often struggle to communicate the significance of damaged textiles, as they no longer convey their original intent and meaning. By reconstructing a possible original state, this project helps to recontextualize the fragments for modern audiences.

Level of Detail and Output

The level of detail chosen for this reconstruction was determined by available evidence and the project's scope. The chosen level of detail, as described by the 4D Research Lab Principles Statement, was LoD4, "a precise modelling of all elements" represented by geometrical content[57]. The focus was placed on accurately restoring the decorative elemants, material textures, and structural design of the original object, ensuring a historically informed representation. Future extensions of this project may explore animation and interactive elements, allowing users to deconstruct the object digitally and gain more insight into its construction and history.[58]

The final output will include:

- 3D models of the textile fragments through photogrammetry, accompanied by a more detailed representation of visual elements through Gaussian Splatting.
- A rendered visualisation demonstrating the fragment's possible original appearance.

Methodology

For this 3D visualisation project, I attempted both virtual reconstruction and virtual restoration to digitally recreate a severely damaged textile object with missing decorative elements. The methods used aimed to restore the original appearance of the fragments while considering historical accuracy and material properties. The final product is an attempt to provide both a restored version of the object and a historically informed reconstruction, bridging the gap between its current damaged state and its likely original form. The model is simultaneously process- and outcome-oriented: Constructing the

[55] ICOMOS, *The Seville Principles* (New Delhi: ICOMOS General Assembly, 2017).

[56] M. Hostettler et al., "Concluding Remarks – Coordinates for the Future of Digitalised Archaeology," in *The 3 Dimensions of Digitalised Archaeology*, ed. M. Hostettler et al. (Springer, 2024), 217–223.

[57] 3D structural/procedural modelling, instead of working with 2D UV maps/textures.

[58] Tijm Lanjouw and Jitte Waagen, 'Making 4D: principles and standards for virtual reconstruction in the humanities by the 4D Research Lab' (University of Amsterdam, July 2021) 9-10.

model offers insight into manufacture, visual properties and material. Furthermore, the outcome is aimed at providing both the academic and lay public with a better understanding of the original appearance of the archaeological fragment.[59]

Virtual Reconstruction

The approach of virtual reconstruction was used to recreate missing elements based on historical evidence. The base of the fragment was scaled and modelled on the 2D reference image in the treatment report, and by using the conservator's measurements. Since the fragments were severely damaged, with many elements (partly) missing or deformed, the reconstruction relied on comparative analysis with similar and contemporary liturgical textiles, art historical references, and documented embroidery techniques. The missing decorative elements were reconstructed using information from these sources (see section 4.3).

Virtual Restoration

The virtual restoration process was aimed at digitally modelling the missing elements in the textile object, following an approach similar to but more extensive than currently favoured textile conservation approaches. The fragments were treated as reference material, and made into a model. Then, new elements were added and existing elements were modelled as if in an original intended state. The aim was to recreate the object's possible original appearance. The modelled materials were applied as if they were newly woven and embroidered textiles, allowing for a clearer visualization of how the chasuble may have originally looked.

Sources

For this project, a combination of academic sources, archival records, condition reports and comparative analysis of similar objects was used. As a general rule, the sources were either selected because of their academic nature and the wealth of information they could provide on the context and visual elements of the object, or based on their proximity (direct interaction and proximity in time) to the object. The combined use of these sources has the aim of supplying the reconstruction with as much historical evidence as possible while acknowledging potential gaps and biases in information in this report. Chapter 6 is dedicated to the discussion of these sources and the comparative analysis of the fragments. This approach is defined as a 'bottom-up' approach, basing hypotheses on the gathered information, as defined by the 4D Research Lab.[60]

5.5 Workflow and modelling process

This section outlines the methodology for reconstructing a coherent object from a set of fragmented archaeological textiles retrieved from the 17th-century Palmhoutwrak (BZN17) shipwreck. Given the fragility and historical value of these fragments, a digital, non-invasive approach is employed that integrates advanced imaging, computational analysis, and 3D modelling techniques. Specifically, the workflow incorporates photogrammetry, Gaussian splatting, and textile modelling through Blender. These technologies allow for a systematic reconstruction that balances visual fidelity with historical plausibility while adhering to international ethical frameworks in digital heritage.

The fragments were documented in situ at the Huis van Hilde depot using a Nikon D750 DSLR camera with a standard lens. Two workflows were employed: one for standard photogrammetry using Agisoft Metashape, and one for high-fidelity image-based rendering using PotShot's Gaussian

[59] Lanjouw and Waagen, *4D Research Lab Principles Statement*.
[60] Denard, Hugh, ed. *The London Charter for the Computer-Based Visualisation of Cultural Heritage*. Version 2.1. King's College London, 2009; Lanjouw and Waagen, *4D Research Lab Principles Statement*.

Splatting. The photogrammetry process followed a consistent imaging protocol of ~80 photographs per fragment, covering two angles each of front and back with approximately 70% overlap. For thread-level analysis, close-up shots were taken at extremely narrow apertures (ISO 100, f/36, 10s exposure), aimed to produce images with a 10 pixels distance from thread center to thread center. No significant preprocessing (e.g., color correction or masking) was performed before model generation.

Photogrammetry Workflow

Photogrammetry is used to capture the 3D geometry and surface texture of the fragments. The process begins with a meticulous photography setup:

- Data Acquisition: Each textile fragment is photographed from 50–100 angles using a DSLR camera. Controlled diffuse lighting is employed to avoid shadows and reflections. Scale bars and coded targets are positioned around the object to ensure dimensional accuracy and alignment. Fragments are placed on a non-reflective surface for full visibility of edges and textures.
- Processing Pipeline: Images are processed using Agisoft Metashape. The software aligns the photos using feature-matching algorithms, constructs a sparse point cloud, and subsequently generates a dense point cloud and textured mesh. The result is exported as an OBJ or PLY file, along with high-resolution texture maps.

Gaussian Splatting

In cases where photogrammetry struggles—due to translucency, reflectivity, or fragment fragility—Gaussian splatting is applied. This technique transforms 3D point clouds into splatted visualizations using 3D Gaussians (these are like pixels that have spatial, textural and visual data included in them), capturing fine detail and structure. Tools such as Unreal Engine or custom Python implementations are used to optimize the density and visual fidelity of the splats.[61] These models could be combined with photogrammetry meshes for comparative analysis in future research.

Quality Assurance

To ensure the accuracy of models, digital measurements (e.g., perimeter and surface area) are compared with measurements taken from the original fragments. Texture fidelity is verified by comparing lighting and colour consistency between physical samples and the digital model.[62]

Hypothetical Reconstruction in Blender

With fragment models finished and documenting them in their current state, the final phase involves simulating the object in its potential original form.

Blender Modelling

- Assembly and extrapolation: The fragments are imported into Blender. Using historical typologies (e.g., tent hangings or garments), plausible missing sections are extrapolated

[61] "Gaussian Splatting Demo," accessed April 2025, https://www.youtube.com/watch?v=ERuRMOVO58Q.

through mesh modelling. Subdivision Surface modifiers ensure organic transitions between digital fills and original fragments.[63]

- Texturing and integration: Original textures are mapped directly onto fragments. New textures for extrapolated areas are generated procedurally and blended into surrounding textures to preserve authenticity.
- Optional rigging: For garments or flexible furnishings, basic rigging is applied to simulate realistic folds and movement, enhancing the interpretative visualisation.
- Material simulation: Mechanical cloth properties are added to simulate draping behaviour.
- Testing and hypotheses: Multiple configurations are tested, iterating on seam placement, cutlines, and drape until the simulated object aligns with archaeological and historical evidence.

Final Integration and Rendering

Blender is used to render the definitive reconstruction. Final lighting, camera, and material shaders are applied to generate a photorealistic render and model.

Format of output

- blender files of the reconstruction model
- files of the photogrammetry/gaussian splatting models
- reconstruction model on google drive (downloadable)
- pdf document, this thesis

5.6 Process summary

Heiloo Fragments

During an earlier course the set of fragments discussed in section 5.2 was modelled in blender, resulting in two models; one of the fragments in a hypothesised original state, complete with materials and textures, and a second one of the hypothesised original state with indications of certainty.

Figure 9 Rendered image of Heilo Madonna fragment reconstruction model.

[63] 4D Research Lab, "Degrees of Certainty Definition v.1," University of Amsterdam, 2020.

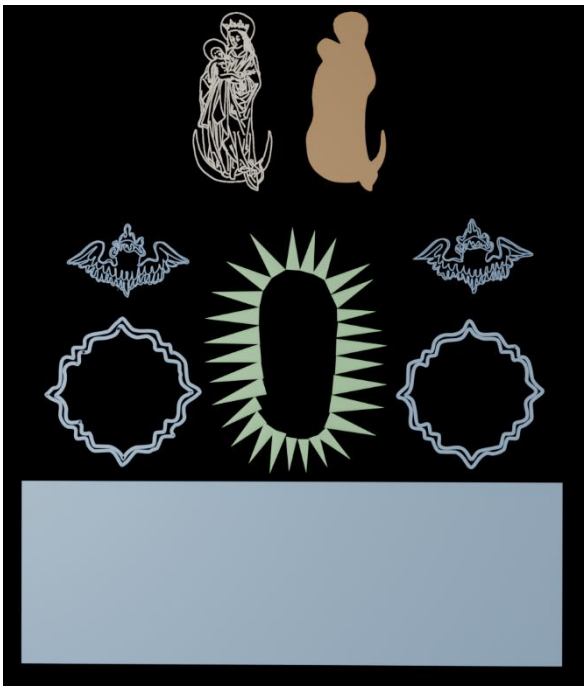

Figure 10 Render of the degrees of certainty of the reconstruction.

During the beginning stages of this thesis project photogrammetry software was tested on a different fragment belonging to the same collection. This fragment (inventory number unknown) has similar characteristics as the BZN17 fragments, as there is no decoration present and the textile is relatively flat, but still folded and slightly deformed.

Figure 11 Test set-up for photogrammetry with one Heiloo fragment.

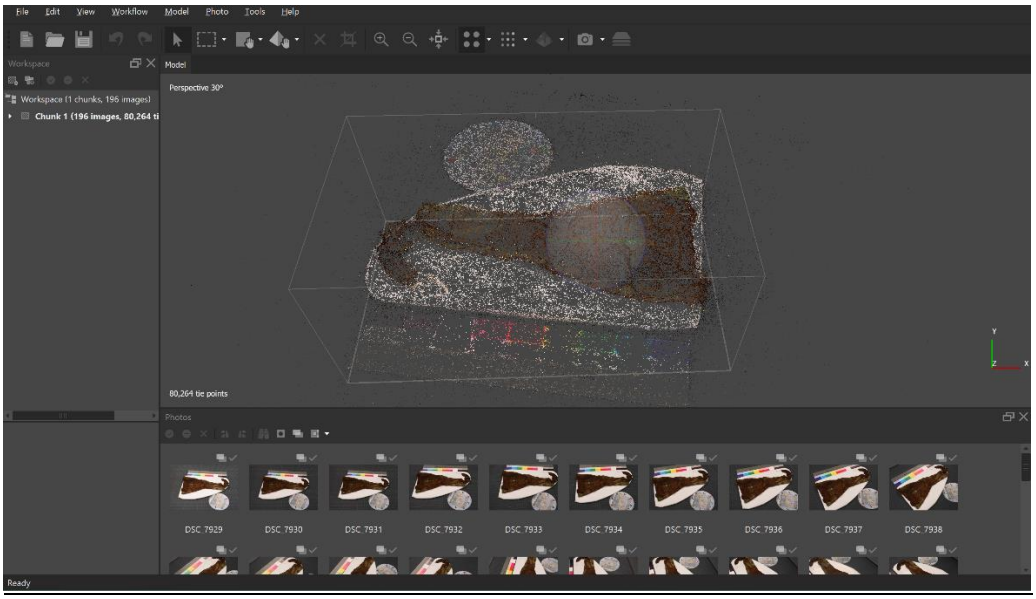

Figure 12 Photogrammetry modelling of the Heiloo fragment in progress, showing a point cloud.

BZN17 Fragments

Images of all the fragments were imported into Agisoft Metashape, they were aligned, converted into a point cloud, which was turned into a mesh/model and finally surface textures were generated (see ch. 7 for the result).

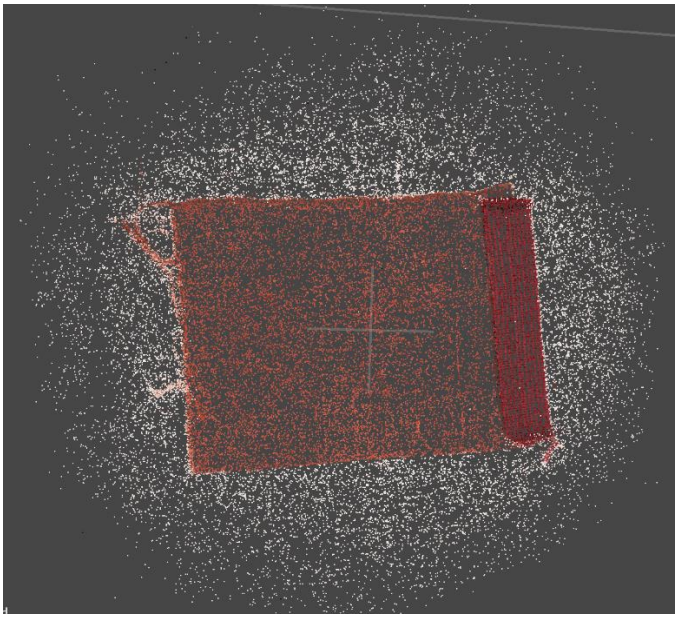

Figure 13 Sparse point cloud, generated for a test object similar to the BZN17 fragments.

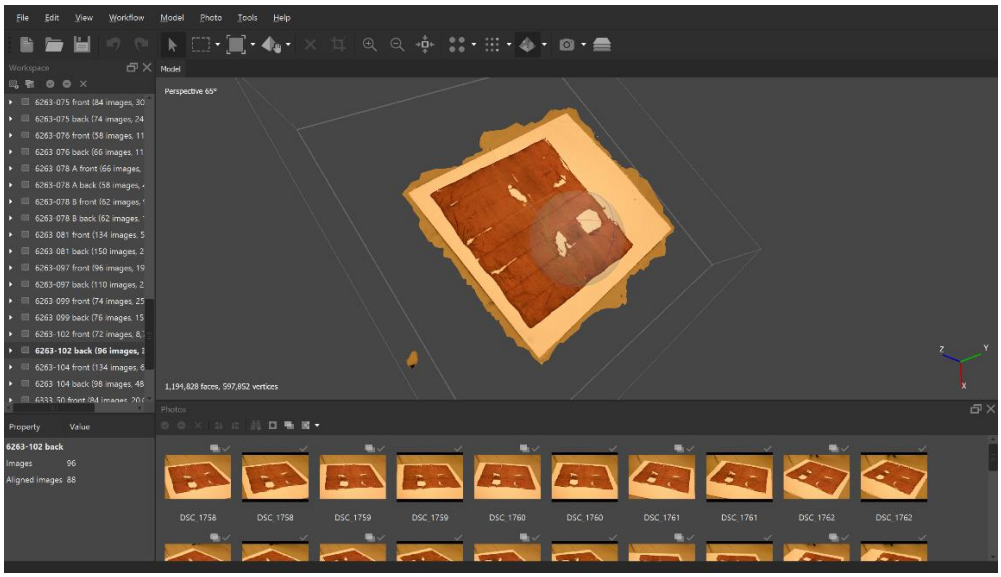

Figure 14 Modelling process of one of the BZN17 fragments (6263-102) in Agisoft Metashape.

The images were also imported into Jawset Postshot, Gaussian Splatting software. This software is extremely user-friendly as it independently goes through all the processing steps and presents the user with a model that only needs to be cleaned. However, due to the amount of time this takes (as the software uses an AI training method, which goes through 30k steps on average) only one fragment was processed.

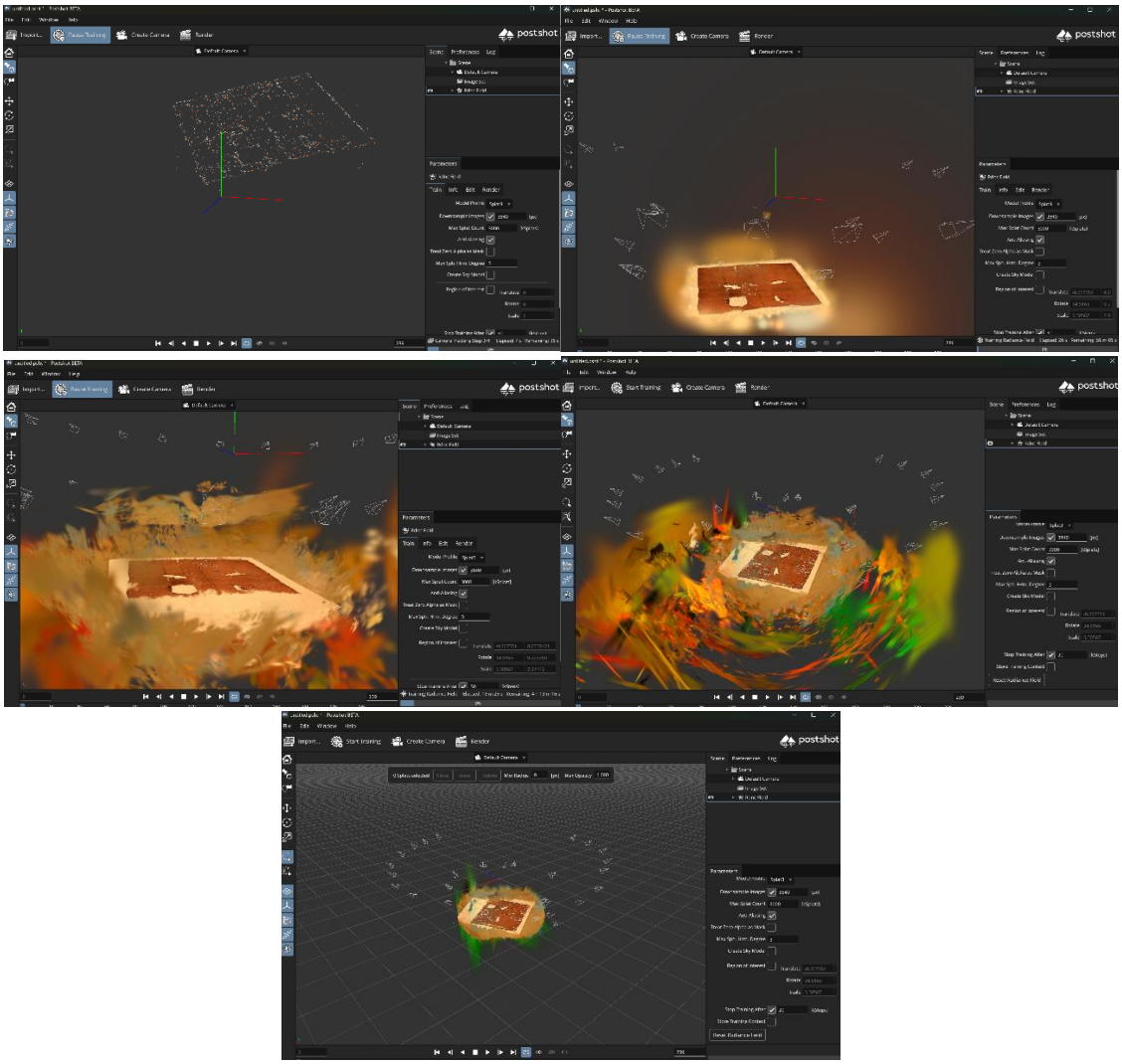

Figure 15 Snapshots of the various steps the gaussian splatting software goes through.

Finally after the fragments were digitalized and analysed, and after comparative research was conducted, a 3D model of a possible original configuration of the bed hangings was made. Using blender, the curtains and valances, with their accessories were modelled based on pictures, measurements and material properties. Only two out of four original curtains were modelled to better show the construction of the bed and its hangings.

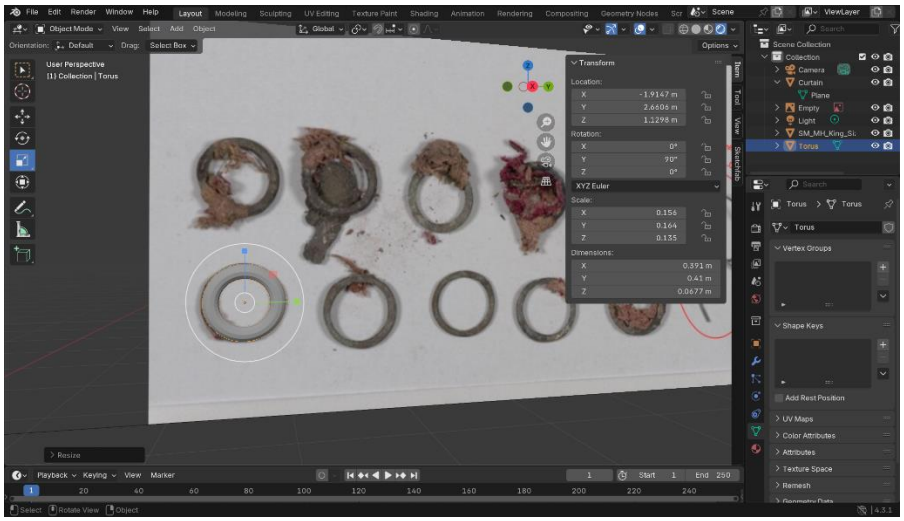

Figure 16 Curtain rings were modelled based on other BZN17 finds.

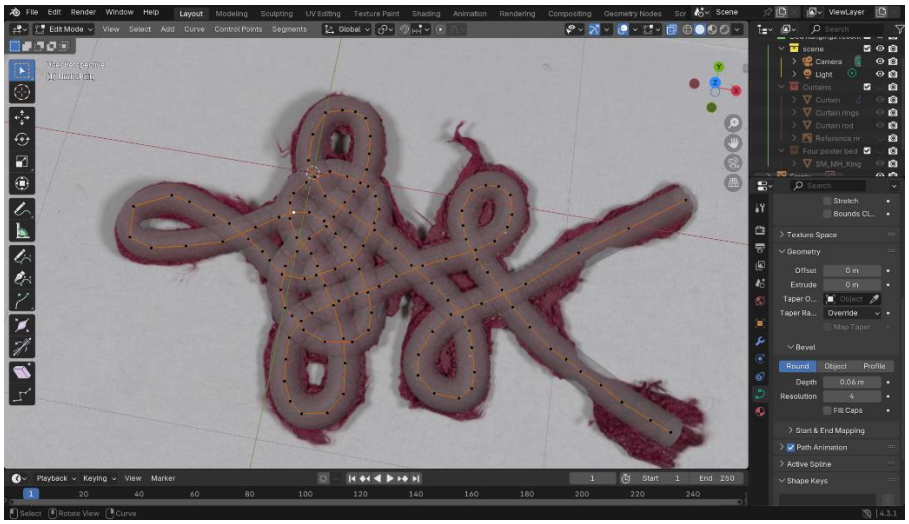

Figure 17 The frog closures were modelled based on reference pictures and accurately scaled.

Figure 18 Materials were chosen based on analysis and historical sources.

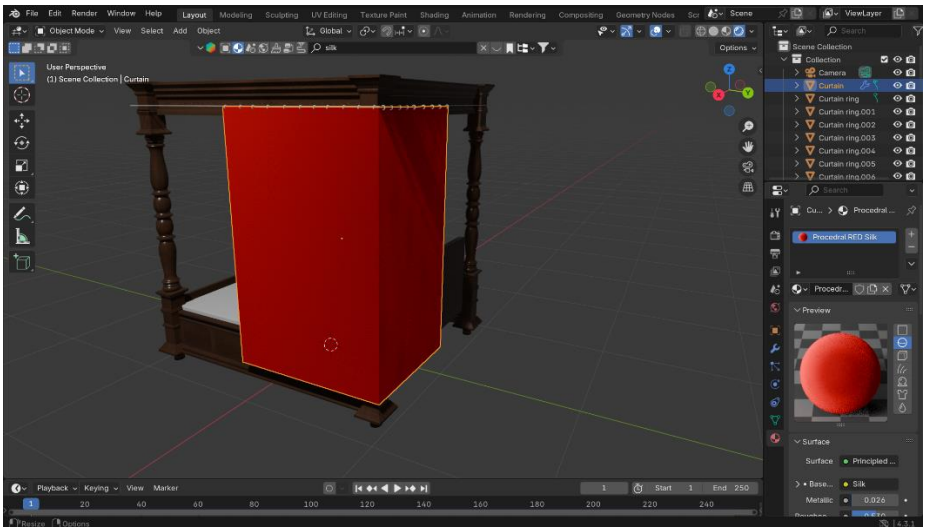

Figure 19 The curtains were suspended from metal rings on a curtain rod.

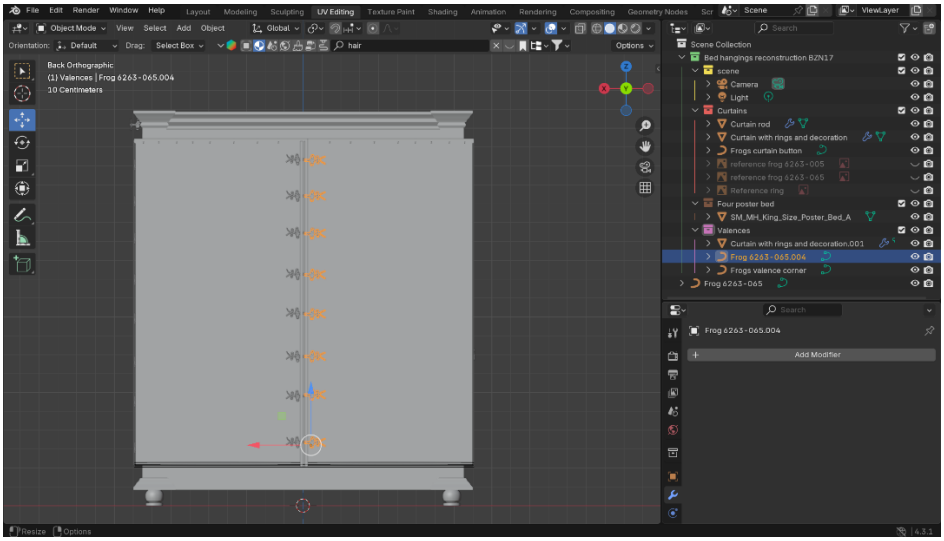

Figure 20 Details and decorations were added based on previous reports and observations.

6. Attribution

6.1 Silk, dyes and trade routes in the 17th-century

The material analysis (see appendices 10.2, 10.3 and 10.4) of the BZN17 fragments (samples 6263-104 and 6263-102) has revealed that the fragments are all made of the same crimson, dyed with insect dyes, silk. The dyes used are a mixture of what appears to be American cochineal and kermes, as well as the possible use of Armenian cochineal. However, historical evidence indicates that Armenian cochineal was no longer actively traded in Europe by the 17th century, making its presence in these fragments historically significant if confirmed, suggesting possible Turkish origins.[64]

The 17th century marked a period of unprecedented expansion and globalization in the production and trade of silk textiles. The production of silk began with the development of sericulture, primarily in regions such as China, Iran (notably the Caspian provinces of Gilan and Mazandaran), Bengal, and parts of Italy. The silk filaments were extracted from the domesticated silkworm (Bombyx mori), the production of which required careful cultivation of mulberry and whose extraction was a very labour-intensive process.[65]

During this period, silk production was tightly interwoven with global trade networks. Chinese and Persian silks had long dominated the Eurasian market, but by the early modern era, the axis of trade began to shift. The rise of the Dutch Republic as a maritime power was instrumental in this transformation. The Dutch East India Company (VOC), established in 1602, quickly became a central player in the long-distance trade of luxury goods, including silks. The VOC established commercial outposts across Asia—in Iran, Bengal, China, and Southeast Asia—and created a direct maritime route linking these centres to Amsterdam via the Cape of Good Hope. In addition, the Italian city states had always been leading in the silk trade and production. From the middle ages until the eighteenth century, the mediterranean silk trade continued to flourish and supplied high quality silk to other parts of Europe.[66]

By the 1620s, the VOC was importing silk not only from Iran but increasingly from Bengal and China, as shifting political and economic conditions rendered the silk imported via their new trade routes more accessible and cost-effective than previously dominant overland routes. Iranian silk, once a mainstay of European imports, gradually lost ground to the finer and more competitively priced silks of Bengal, especially as European markets demanded consistent quality and colour, including vibrant reds achieved with imported dyestuffs such as cochineal and kermes.[67]

Amsterdam emerged as a key hub in this network. The city's silk markets and workshops flourished, serving both as a point of distribution for imported Asian silks and as a centre for finishing,

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[64] Nurhan Atasoy et al., *İpek: The Crescent & the Rose: Imperial Ottoman Silks and Velvets*, comp. and ed. Julian Raby and Alison Effeny (London: Azimuth Editions on behalf of TEB İletişim ve Yayıncılık A.Ş., 2001), 132.

[65] Amanda Phillips, *Sea Change: Ottoman Textiles between the Mediterranean and the Indian Ocean* (Oakland, California: University of California Press, 2021) 20-21; Elisabeth A. Fraser, "Introduction: The Mobility of People and Things in the Early Modern Mediterranean: The Art of Travel," 1-8; Atasoy et al., *İpek: The Crescent & the Rose*, 195-202.

[66] Matthee, "The Dutch East India Company and Asian Raw Silk," 76-78, 84; Schulz, "Entangled Identities," 121; Amanda Phillips, "The Localisation of the Global: Ottoman Silk Textiles and Markets, 1500-1700," in *Threads of Global Desire: Silk in the Pre-Modern World*, ed. Dagmar Schäfer, Giorgio Riello, and Luca Molà (Suffolk: The Boydell Press, 2018), 103-123, 108; Suraiya Faroqhi, "Ottoman Silks and Their Markets at the Borders of the Empire, c. 1500-1800," in *Threads of Global Desire: Silk in the Pre-Modern World*, ed. Dagmar Schäfer, Giorgio Riello, and Luca Molà (Suffolk: The Boydell Press, 2018), 127-147, 145-6.

[67] Matthee, "The Dutch East India Company and Asian Raw Silk," 91-94; Dagmar Schäfer, Giorgio Riello, and Luca Molà, eds., *Threads of Global Desire: Silk in the Pre-Modern World* (Suffolk: The Boydell Press, 2018), 156.

dyeing, and weaving luxury textiles. Dutch merchants imported raw and semi-finished silks, which were then dyed—including in the highly desirable crimson shades—and woven or re-exported across Europe. The technical expertise in dyeing and finishing, along with the cosmopolitan nature of Amsterdam's merchant community, enabled the city to become a big supplier of fashionable silks both on domestic and international markets.[68]

The dyes used for these fragments align with the trade and production processes of red dye in the seventeenth century. By this time, American cochineal had been introduced to European markets by Spanish traders from Mexico starting in the 1520s, offering a vibrant crimson color comparable to traditional Old World insect dyes. The traditional European kermes (Kermes vermilio) and various Porphyrophora species, including Polish and Armenian cochineal, had been extensively exploited across Europe and Asia until previously and now took a backseat. This type of cochineal produced more vibrant and stable reds than traditional European dyes like kermes or Polish cochineal. Its adoption accelerated after Flemish weavers and dyers, fleeing religious conflict, settled in Dutch cities such as Leiden and Amsterdam, bringing advanced dyeing techniques. Cochineal, derived from insects bred in Mexico and monopolized by the Spanish Crown, became highly valued due to its vivid colour and efficiency, requiring far fewer insects to dye textiles compared to traditional sources. Its spread across Europe depended on local economic, political, and social factors; for example, Italian silk dyers in Venice adopted cochineal in the 1540s to reduce costs, while regions like Portugal continued using native kermes into the eighteenth century. By the mid-17th century, silk production emerged in cities like Amsterdam and Haarlem, often overseen by French and Italian experts. Silk dyeing recipes and surviving fabric swatches confirm the widespread use of cochineal, sometimes mixed with Polish cochineal. Thus, cochineal became central to luxury textiles in the Netherlands, shaped by both regulatory limits and immigrant expertise.[69]

The presence of red silk textile fragments in the Netherlands today can be directly attributed to this dynamic 17th-century context of global trade. Whether produced locally from imported thread or arriving as finished goods, these textiles reflect the Dutch Republic's pivotal role in the global silk trade—a role built on maritime prowess, commercial innovation, and the ability to connect Asian production centres with European consumers.[70]

6.2 Connecting the fragments

When considering all fragments, it is very likely, based on the materials, decoration and panels, that they once formed the hangings of a 17th century four-poster bed. Material and dye analysis indicated that the fragments are all made of the same crimson silk, even fragment 6263-051, which is notably lighter than the rest. All fragments have the same decoration of a more saturated true red trim around the edges, accompanied by frog fastenings and sometimes a fringe, which van be long or short.

The two largest objects in the group – complete panels 6263-102 and 6263-104 – offer the most information about the likely structure and look of the original set. Fragment 6263-102 measures 172 cm in height and 200 cm in width and features eight female frog fastenings along each

[68] Matthee, "The Dutch East India Company and Asian Raw Silk," 91-94; Schäfer, et al., *Threads of Global Desire*, 156.
[69] Serrano, et al., "Crimson, Black, Silver and Gold,"; Serrano et al., "Investigation of Crimson-dyed Fibres,"; Ana Serrano, "Cochineal and the Changing Patterns of Consumption of Red Dyes in Early Modern European Textile Industries." 348-349, 356-357, 360-362, 365-367; Schulz, "Entangled Identities", 132; Serrano, et al., "The Colors of a Lavish 17th-Century Finding off the Coast of Texel," 3-4

[70] Matthee, "The Dutch East India Company and Asian Raw Silk," 78, 98-101; Phillips, *Sea Change*, 32-33.

vertical side. It includes a narrow fringe along the bottom and both sides, bilateral symmetrical damage, and a tape stitched at the top edge. Fragment 6263-104, slightly narrower (190-200 cm wide, 170 cm high), mirrors this layout with male frog fastenings and similar fringe and reinforcement features. However, it has been distorted into a bow-like shape due to the presence of an unknown substance, possible metal corrosion contaminations, which stuck the middle part of the fragment to itself. The substance is likely non-original material introduced post-deposition, during its time underwater. Another sizable fragment, 6263-051, appears to be a central section of a larger curtain panel.

Two fragments offer likely examples of curtain corners. 6263-030 includes three male frog fastenings and remnants of top-edge reinforcement tape, where loops or rings could have been attached, suggesting a top-left curtain corner. 6333-51, by contrast, has a single male frog along one side and fringe along both edges, indicating it may come from a left, lower corner.

Fragments identified as corners of the top valances—fragments 6263-052, -053, and -081—consist of two parts of separate panels that have been sewn together, each with three sets of male and female frogs. These decorative fastenings are likely the elements that would connect the top valance panels at the corners. Their wide fringes and symmetrical construction are consistent with valances that would have spanned between bedposts along the top edge of the structure.

Additional edge fragments with individual frogs are evidence that there may have been more material that may have belonged to other curtain panels. This suggests, based on the distribution of the closures on the two complete panels with only a single type of closure per panel, that there would have been at least two more curtains. Other isolated elements, along with the frog-bearing edge fragments, suggest a wide distribution of attachment points across what was likely a modular and symmetrical hanging system. The frogs on these curtains would have served as functional closures along the vertical edges of curtain panels.

Fragment ID	Features	Interpretation
6263-102	200W × 172H cm, 8 female frogs/side, fringe, reinforced top	Complete curtain panel
6263-104	170H × 190–200W cm, 8 male frogs/side, fringe, reinforced top, bow-shaped	Complete curtain panel
6263-051	70H × 36.5W cm, folded, mirrored damage, double-layered	Center panel segment
6263-030	Top edge reinforcement, 3 male frogs on left side	Curtain corner (top left)
6333-51	Male frog on left, fringe around edges	Curtain corner (bottom)
6263-052	Sewn edges, 3 sets of M+F frogs, wide fringe	Valance panel
6263-053	Sewn edges, 3 sets of M+F frogs, wide fringe	Valance panel
6263-081	Sewn edges, 3 sets of M+F frogs, wide fringe	Valance panel
6263-054	Fringe only, no frogs	Edge trim or valance base
6263-055 to -078	Single frogs (mostly male), partial fabric and edge trim	Curtain edges or connectors
6263-097	Long strip of wide fringe, no frogs	Edge trim or valance base
6263-099	Male frog with longer side edge trim	Curtain edge
6333-50	1 male + 1 female frog, sewn shut	Part of a valance panel

Loose frogs (e.g., -002, -066, -076, -001, -063, etc.)	Isolated frogs, no attached fabric	Detached closures for reassembly

Seventeenth-century beds typically featured between three and six curtain panels, and often included a headcloth behind the headboard. In some cases, a single large curtain may have wrapped around the head of the bed, extending halfway both sides, with two smaller panels enclosing the foot end. It could also have been two curtains at the head and two at the foot. These configurations align with examples seen in contemporary illustrations and inventories of elite portable or ceremonial beds.

Analysis of frog placement across the collection supports the reconstruction of at least four full curtain panels, with sufficient fragments and fastenings to suggest a fifth partial curtain or fixed head drape. Each curtain panel likely included eight frogs per side, totaling sixteen fastenings per panel. A full count of frogs across complete panels, partial edges, and loose frog fragments supports the reconstruction of at least four operable curtains, and possibly a fifth partial panel or fixed headcloth. Valance panels, characterized by decorative sewn-together frogs, were likely installed above the curtains, spanning horizontally between the posts and helping to form a framed canopy.

Although exact pairings of edge fragments remain uncertain, the uniformity in fringe length, frog spacing, and top-edge reinforcement allows a functionally coherent reconstruction hypothesis. Combined with the known full panels and probable corner and valance sections, the textile fragments form a plausible representation of a four-poster bed hanging set typical of 17th-century aristocratic interiors or portable travel furnishings.

Several other textile or textile related finds from the BZN17 shipwreck might also have been part of the set of bed furnishings, as they have the same crimson shade (and silk, although different types of weaves) or are details that could be connected to bed furnishings. A group of fragments in a crimson damask[71] could be a candidate for additional hangings, like a headcloth, as damask was a popular furnishing fabric and one of the objects still has curtain rings attached to it[72]. Several loose, copper curtain rings have also been found,[73] to some which fragments of red fabric are still attached. There are also some woven red rings in the collection[74], as well as a couple of red teardrop shaped buttons or small tassels.[75] And finally there is a piece of red damask thought to be part of a pillow case.[76]

Figure 21 Object 6261-001, curtain rings. Image courtesy of the Huis van Hilde.

[71] Objects 6263-008, -046a,b to -047, -049 to -050, -057, -079 to -080, -137 and 6333-52.
[72] Object 6263-137.
[73] Objects 6261-001 to -004, -016, 6333-42, 6305-77.
[74] Objects 6333-43, 6261-009 to -011, 6333-53 and 6262-012.
[75] Objects 6261-005 to -008, 6333-40, -4.
[76] Object 6263-048.

6.3 Historical sources: beds and bed-hangings.

In the 17th century, the bed was not merely a utilitarian item but the most prominent piece of furniture in most households. Its centrality was not only practical—as it provided warmth, privacy, and comfort—but also symbolic, because it expressed the wealth and status of its owners. This section will discuss the developments in bed construction, the use of luxurious textiles, and the proliferation of elaborate decorative finishes, particularly in the context of elite and increasingly affluent bourgeois interiors in Northern and Western Europe.

Figure 22 David in Prayer, Rembrandt van Rijn, 1652. Print, 15.4 cm x 10.7 cm, Victoria & Albert Museum.

Bed Construction

The most common type of bedstead in the 17th century was the four-poster bed, also known as the "lit à colonne" in France or the "box-shaped bed". These beds featured four posters at the corners, supporting a horizontal frame called the tester, that acted as a sort of canopy, and from which bed hangings and valances were suspended. In England, as well as in the Dutch Republic and France, these beds could be substantial in size, with widths ranging from 90 to 200 cm. The construction usually involved a wooden frame made of oak, walnut, or beech, although the frame itself was often of secondary importance compared to the hangings. The posts ranged from plain to highly ornamented, with carved decorations, gilding, and even precious stones in some cases.[77]

[77] Mei Mei Rado, “Le Rideau Tiré: Drapery, Architectural Space, and Desire in Eighteenth-Century France” (65-82) 65-69; Abbott Lowell Cummings, Bed Hangings: A Treatise on Fabrics and Styles in the Curtaining of Beds 1650-1850 (The Society for the Preservation of New England Antiquities, Boston, 1961) 7-11; Peter Thornton, Seventeenth-Century Interior Decoration in England, France and Holland

Dutch beds in particular could also take the form of box-beds, enclosed on three sides by wooden panelling, with a curtain across the open side. While aristocratic beds in France and England tended to stand out from the wall as a focal point, beds in the Low Countries were often placed in corners or even built into the wall, a practice that gradually gave way to more French-influenced fashion by the late 17th-century. This change in fashion was particularly influenced by the Stadholder court in the Hague, with Frederik Hendrik (succeeded 1615, died 1647), who had a partially French background, being a strong proponent.[78]

Textile Furnishings: Hangings, Valances, and Accessories

The defining feature of a 17th-century bed was its elaborate textile furnishings. A set of bed hangings was made up of various elements: curtains, valances, headcloths, tester cloths, counterpanes (bedspreads), and base valances (skirts covering the lower frame). The bed hangings were typically made up of multiple curtains—four being the most common number, though exceptionally grand beds might have as many as six. Curtains hung from rods, often of iron, horn, or copper, suspended by rings, tape loops, or metal rings sewn onto the fabric. Lead weights could be added to help heavy fabrics drape attractively.[79]

(Yale University , New Haven, 1990) 154-157; Pamela Clabburn, *The National Trust Book of Furnishing Textiles* (Penguin Books, London 1989) 99.

[78] Clabburn, *Furnishing Textiles*, 158-159; Henriëtte Helena Domissie, *Het Hollandse Pronkpoppenhuis: Interieur en huishouden in de 17e en 18e eeuw* (Waanders Uitgevers, Rijksmuseum, Amsterdam, 2000) 86-87; Cummings, *Bed Hangings*, 7-11; Thornton, *Seventeenth-Century Interior Decoration*, 36-43.

[79] Cummings, *Bed Hangings*, 7-11; Peter Thornton, *The Italian Renaissance interior 1400-1600* (London : Weidenfeld and Nicolson, 1991) 161.

Figure 23 Sir Henry Guildford (1489-1532), Hans Holbein the Younger (1497/8-1543), 1527. Oil on oak panel, 82.7 cm x 66.4 cm, Windsor Castle, Royal Collection Trust.

Valances were an essential feature, attached around the edges of the tester to conceal the curtain rods and rings. These could be double (inner and outer), the outer often being more elaborately decorated. Valances were usually cut as four separate pieces—one for each side, one for the head and one for the foot—and could be sewn or fastened together at the corners. They were sometimes attached with eyelets and hooks, or tacked directly to the tester frame.[80]

The headcloth served as a back panel behind the pillows and head board, and the tester cloth formed the canopy overhead. Counterpanes or *courtepointes* covered the bed during the day and were often shaped to fit around the posts. Base valances, or *bases* (also called *pantes* or *soubassements*), hung from the lower frame to the floor, concealing the bed's legs and the space beneath.[81]

Materials and Textiles

The textiles used for bed hangings were expensive and varied, reflecting the status of their owners. The most desirable materials were silks, including taffeta, damask, cut and ciselé velvet, satin, gauze, muslin, and printed or painted cotton. Damask was especially favoured for beds, wall coverings, and curtains, as well as taffeta, often in plain, striped, or floral patterns and a range of vibrant colours—crimson, blue, yellow, and green being particularly popular. Crimson, dyed with costly cochineal or

[80] Cummings, *Bed Hangings*, 7-11.
[81] Idem; Clabburn, *Furnishing Textiles*, 100.

kermes, was the most prestigious colour and frequently associated with beds and state rooms. From the sixteenth to the seventeenth century, the materials got thinner, as insulation of houses improved.[82]

Figure 24. A bed with crimson wool hangings and three pairs of buttons and loops at the corners of the outer valances, c. 1671. Red room, Cotehele, Cornwall.

The introduction of Asian and Middle Eastern silks, as well as Indian cottons, increased the variety and availability of luxurious textiles, particularly in England and the Netherlands following the expansion of global trade through the Levant and the East India Companies. However, much plain silk was still woven domestically using imported raw materials from Italy or Asia. Italian and later French workshops were renowned for their production of high-quality silks and trimmings, with Italy supplying much of Europe from the Middle Ages onwards until French production eventually overtook the Italian by the late 17th century.[83]

Lining materials for bed hangings were typically of a lower grade, such as taffeta, sarcenet (a very thin and light plain weave silk) or armozin (a type of satin), but could nonetheless provide a contrasting color or additional decorative effect. The practice of lining curtains became more widespread in the later 17th and 18th centuries, though unlined curtains persisted for their ease of handling.[84]

[82] Rado, "Le Rideau Tiré," 68; Cummings, Bed Hangings, 54-57; David M. Mitchell, "Fashions in Bed and Room Hangings in London 1660-1735" (21-34), 23; Jolly, *Furnishing Textiles*, 34.
[83] Mitchell, "Fashions in Bed and Room Hangings, 25-27, 29; Catherine Donzel and Sabine Marchal, L'Art de la Passementerie et sa Contribution à l'Histoire de la Mode et de la Décoration (Chêne, 1992) 38.
[84] Aagje N. Gosliga, Le meilleur métier: Kamerbehangers en de aankleding van interieurs in de

Figure 25 A woman at her toilet, Jan Steen 1663. Oil on panel, 65,8 x 53 cm, Royal Collection of the United Kingdom.

Decoration: Trimmings, Passementerie, and Embellishments

A common feature of 17th-century bed hangings was their rich ornamentation with trimmings, known in French as *passementerie*. This type of decoration included fringes, braids, cords, tassels, ribbons, buttons, and gimps, made from silk, wool, and sometimes metal threads. Passementerie served both decorative and practical functions: it protected the edges of hangings from wear during removal, washing, or disassembly, and visually defined the various elements of the ensemble.[85]

Fringes were particularly popular, found on valances, curtains, testers, and counterpanes. They ranged from simple to highly elaborate, with types such as inch fringe, caul fringe, tufted fringe, snailing fringe, gimp fringe, and vellem fringe, often embellished with metal threads, tufts, or buttons. Trimmings were usually colour-matched to the main textiles and, in luxurious examples, could be more valuable than the fabric itself.[86]

Buttons and loops were another distinctive feature of bed hangings, used to connect valances

periode 1680-1810 (Zaandam, 2023) 43-45; Thornton, *The Italian Renaissance interior,* 158; Jolly, *Furnishing Textiles*, 23; Thornton, Seventeenth-Century Interior Decoration, 115-116.

[85] Donzel and Marchal, *L'Art de la Passementerie*, 10-16; Anna bel Westman, "Extravagant Embellishment: Trimmings on State Beds in Britain, 1660-1700" (35-46) 35; Xavier Petitcol, "Les lits à la duchesse en toile emprimée et leurs finitions (95-108) 105; Nadège Gauffre Fayolle, "La passementerie dans la garde-robe aristorcratique à la fin du Moyen Âge. Rubans, tissus, bisettes, tresses ou cordons" (17-34).

[86] Jolly ed., *Furnishing Textiles*, 35-36, 39;

at the corners or as purely decorative elements, often made of silk-wrapped wire or vellum. Ribbons or tapes could be applied to the edges to reinforce them or to conceal raw seams.[87]

Figure 26 Four upholstered Milanese beds, unknown draughtsman, around 1540. Fondazione Querini Stampalia, Venice.

[87] Thornton, *Seventeenth-Century Interior Decoration*, 177; Clabburn, *The National Trust Book of Furnishing Textiles*, 104-105; Westman, *Fringe, Frog & Tassel*, 14.

Figure 27 Portrait of Frederik Hendrik, Prince of Orange-Nassau, workshop of Michiel Jansz van Mierevelt, around 1632. Oil on panel, 111.5 cm x 87.7 cm, Rijksmuseum Amsterdam.

Figure 28 Deathbed of Prince Maurits, Jan Hendriksz. Verstraelen, 1625. Engraving print, 194 mm x 292 mm, Rijksmuseum Amsterdam.

Social and Symbolic Roles

Aside from their practical function in providing warmth, privacy, and comfort, bed hangings were a critical indicator of wealth and status. The most lavish beds—particularly the ones in royal courts and their directly surrounding circles, called "state beds"—were focal points in elite interiors, used for ceremonial display and even as sites for receiving guests. Inventories and paintings from the period confirm that the textile furnishings, rather than the wooden frame, were the main components that impacted the bed's value and visual impression. In the Dutch context, beds and their hangings are frequently among the most valuable possessions listed in household inventories, with matching sets for beds, chairs, tables, and wall coverings creating cohesive, fashionable interiors.[88]

Figure 29 Interior with a Woman at the Virginal, Emanuel de Witte (between 1665 and 1670). Oil on canvas, 77.5 cm x 104.5 cm, Cultural Heritage Agency of the Netherlands Art Collection.

The frequent updating of clothes, in line with changing seasons and fashions, contrasted with the slower changes in trends for textiles, even in extremely wealthy households. So when choosing the textiles for a house or room, or refurnishing it, emphasis was placed on the importance of having good eye for making choices that would remain to be considered tasteful for a while. This further

[88] Rado, “Le Rideau Tiré”, 67; Westman, “Extravagant Embellishment”, 35; Clabburn, *Furnishing Textiles*, 99-100, 104-105; Domissie, *Het Hollandse Pronkpoppenhuis*, 112; Thornton, *Seventeenth-Century Interior Decoration*, 103-104; Peter K. Thornton and Santina M. Levey, *Of houshold stuff : the 1601 inventories of Bess of Hardwick* (Woodbridge, National Trust, 2001); Peter Thornton and Maurice Tomlin, *The furnishing and decoration of Ham House* (London, Furniture History Society, 1980).

underscores the importance of these furnishings as both status symbols and vehicles for personal taste, as they were extremely costly.[89]

The 17th-century bed was a complex and symbolic object, defined by its robust construction, elaborate textile hangings, and sumptuous decorative trimmings. These elements combined to create a powerful statement of wealth and status, with the choice of materials and the skill of the upholsterer or passementier often being considered more important as the carpenter's craftsmanship. The rare surviving examples of bed hangings from this period (very few of Dutch origin) offer a tangible connection to the rich material culture and social hierarchies of the early modern home. This makes the group of fragments from the BZN17 even more valuable as a source of information.[90]

6.4 Textile mobility and climate considerations

The thin, lightweight nature of this group of BZN17 silk fragments raises important questions about their intended use and geographical origins. While section 6.1 has focused on Dutch production capabilities and trade networks, the physical characteristics of these textiles suggest they may have been manufactured for a different climate than that of Northern Europe.

The choice of fabric weight in bed hangings was closely tied to practical considerations of climate and comfort. Thick materials such as tapestry and velvet could be suitable for winter, but too warm and dusty for summer. This led to the practice of seasonal rotation of textiles in wealthy households, with lighter materials being preferred in warmer months and regions. The thin silk of the BZN17 fragments fits with this pattern of climate-adapted textile production. Important to note however, the increase in comfort in houses during the seventeenth century, led city elites to favour lighter materials for their furnishing. Insulation improved as houses were increasingly made of brick, with better functioning chimneys and better fitting doors and windows reduced drafts. As a result, the textiles used for bed hanging were no longer required to be as thick as they used to be. Furthermore, the practical advantages of lightweight silk extended beyond climate considerations. As noted in Italian Renaissance sources, lighter weight silks were the easiest to manage for bed hangings, as the curtains had to be of a material that could easily be pulled and draped. This functional requirement may have made southern-produced lightweight silks attractive to northern consumers.[91]

The mobility of luxury textiles in the early modern period provides crucial context for understanding these fragments. Since medieval times, textiles had served as portable displays of wealth and status, easily transported between locations as circumstances required. Even as aristocratic life became more sedentary after 1500, the tradition of textile mobility persisted through trade networks and diplomatic exchange. Cross-cultural encounters frequently involved the exchange of luxury fabrics as diplomatic gifts, and textiles continued to move across vast distances as both commodities and symbols of prestige. The Mediterranean and Ottoman markets present particularly compelling alternatives for the origin of these lightweight silk hangings. The Ottoman Empire's extensive silk production centres, particularly in regions like Bursa, specialized in creating textiles suited to warmer climates. These workshops produced silk hangings that were both luxurious and practical for Mediterranean and Middle Eastern conditions—characteristics that match the BZN17

[89] Clare Browne, “Silk Damask Bed Furnishings in the Early Eighteenth Century – Influences on Choice of Colour and Design” (47-58) 47.
[90] Petitcol, “Les lits à la duchesse en toile emprimée et leurs finitions”, 95.
[91] Clabburn, *The National Trust Book of Furnishing Textiles*, 28-29. Mitchell, “Fashions in Bed and Room Hangings,”34; Rado, “Le Rideau Tiré,” 65,70; Thornton, *Seventeenth-Century Interior Decoration* 105-106; Thornton, *The Italian Renaissance interior*, 158, 161.

fragments' combination of high-quality materials and lightweight construction.[92]

The presence of such lightweight, high-quality silk fragments on this merchant vessel therefore suggests multiple possible scenarios: textiles traveling from Mediterranean or Ottoman production centres to northern markets, textiles being transported for wealthy travellers, or luxury goods moving as part of the broader patterns of diplomatic and commercial exchange that characterized 17th-century European-Mediterranean relations.

The combination of material analysis, historical documentation, and comparative study makes it very plausible that this group of BZN17 fragments once formed the hangings of a seventeenth-century four-poster bed. The crimson silk's dye —combining American cochineal, kermes, and possibly Armenian cochineal—aligns with European and Mediterranean trade networks and dyeing practices of the period. The systematic analysis of fastenings, fringes, and panel dimensions supports the reconstruction of at least four curtain panels and four valances, consistent with contemporary bed-hangings from inventories and images. This historical framework, combined with the established provenance and construction details, provides the foundation for creating an accurate digital reconstruction that can visualize how these fragments functioned as a complete textile ensemble within their original seventeenth-century context.

[92] Thornton, *Seventeenth-Century Interior Decoration*, 97; Mitchell, "Fashions in Bed and Room Hangings," 25-27; Schulz, "Entangled Identities," 120; Thornton, *The Italian Renaissance interior*, 69-70.

7. Discussion and Results

This chapter presents the digital reconstruction process of the textile fragments from the BZN17 shipwreck (as well as that of the preliminary study of the Heiloo fragments). The research has the aim to virtually model these fragments and to form hypotheses about their original configuration, object type, and function. Finally the outcome of the 3D reconstruction is discussed. This chapter outlines the observations, encountered challenges, and the conclusions on the nature of these objects and their final digital visualisation.

7.1 Photogrammetry process and 3D model development

The fragments were documented at the Huis van Hilde depot with a DSLR camera Due to the size and state of the fragments—many of which were frayed, twisted, or curled —some adjustments in angle and focal depth were necessary. Overhead fluorescent lighting was used, as studio lights caused excessive glare, and this was the available lighting at the Huis van Hilde depot. Close-up shots were also taken, with the aim of using them for computer aided thread analysis, however, image clarity and stitching of the images at this scale were inconsistent, limiting the current potential for computer-aided weave alignment. Despite working in a non-ideal environment (a low-light basement workspace), the resulting models from Agisoft were dimensionally informative, though not highly detailed and some with errors due to the lighting conditions. In contrast, Gaussian splatting provided richly detailed renderings but lacked the solid geometry. Both techniques required an extremely high amount of processing, that would have taken too much time, which led to the decision to use the rough photogrammetry models as a result for this project and a trial run of a single Gaussian Splatting model. These two techniques can be used in tandem to attain optimal digital visualisations in future projects.

The challenge of this particular project is that with the two visualisation techniques, the mostly 2D textiles are treated as 3D objects, which involves many complications. These techniques traditionally work well for 3D objects such as garments or even better stiffer objects such as pottery. Still, both photogrammetry and Gaussian splatting are useful for visualising and digitally preserving these textile fragments, and with some adjusting and finetuning this technique could be perfected. For future attempts better conditions are paramount, such as to test the full capacity of the techniques with the proper lighting and enough time to take higher quality and more pictures. In the case of Gaussian Splatting, tests could even be done with video.

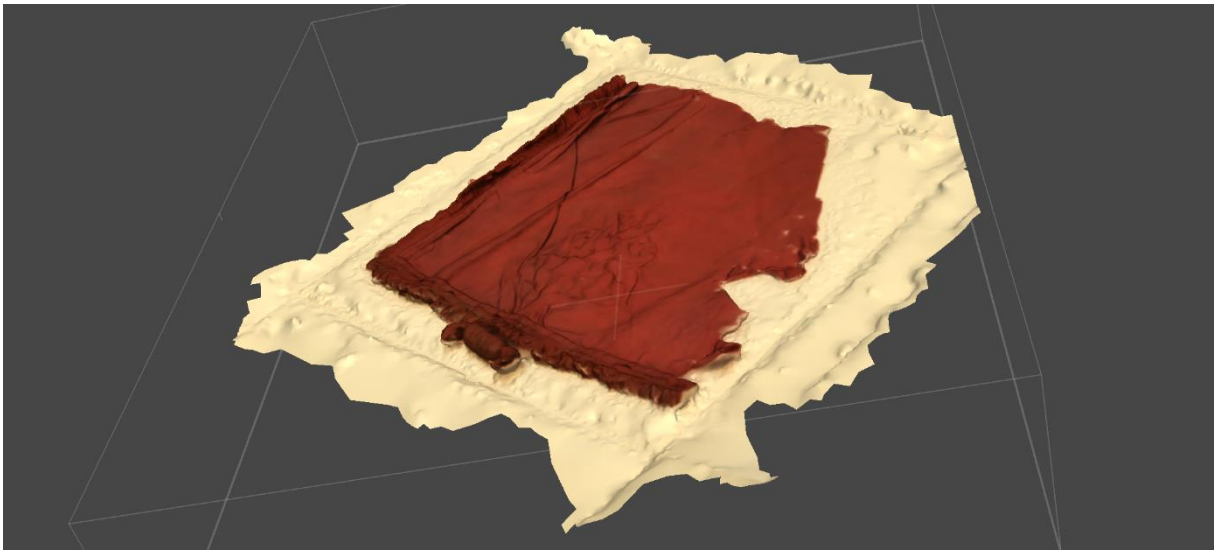

Figure 30 Photogrammetry of underside of fragment 6333-51.

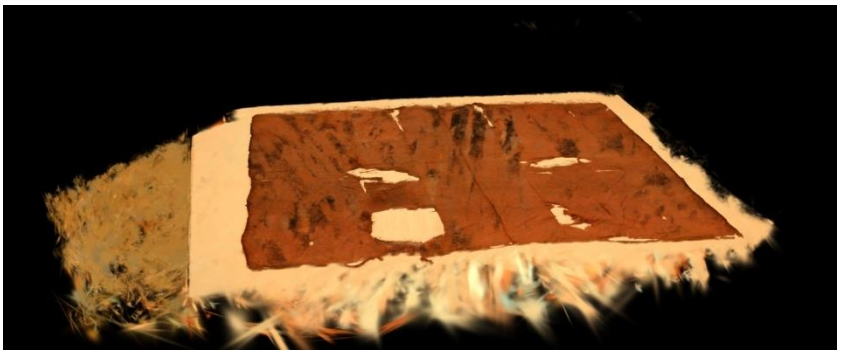

Figure 31 Gaussian Splat of 6263-102 (back).

The modelling process of the reconstruction was fairly straightforward. The bed was adapted from a model downloaded from Sketchfab[93] and the hangings were modelled according to the measurements of the fragmetns (see Appendices 10.1 and 10.6). However, due to time constraints, a more sophisticated reconstruction using CLO3D was not attempted. This was in part due to the author being unfamiliar with the software, in contrast to Blender, and the fact that CLO3D seems best suited for garment modelling, whereas these fragments are fairly two-dimensional and do not require the type of pattern drafting and construction garments might.

[93] James Moore, *Kingsize Poster Bed with Mattress and Pillows* (accessed 20-6-2025). https://sketchfab.com/3d-models/king-size-poster-bed-with-mattress-and-pillows-5acbed3d0a1f428c91122c175eaab5fd

Figure 32. Rendered images of the bed furnishings reconstruction.

This link provides access to the working file with the photogrammetry models as well as the photogrammetry test and the reconstruction model:

https://drive.google.com/drive/folders/12QsKohw5B9DILX2hteRt4Oppts3FkT2h?usp=sharing

To view the models the right software is required[94], these are links to free viewers:

- Agisoft Viewer, photogrammetry: https://www.agisoft.com/downloads/installer/ (scroll down).
- Postshot, gaussian splatting: https://www.jawset.com/
- Blender, reconstruction model: https://www.blender.org/download/

7.2 Integration of modelling process and historical attribution

One of the most significant contributions of this thesis lies in the integration of technical reconstruction methods with historical and material analysis, creating an interdisciplinary approach that helps to situate the BZN17 textile fragments within their plausible seventeenth-century context. This fusion allowed for a more complete understanding of both the physical characteristics of the fragments and the socio-historical function of the original object.

While photogrammetry provided a geometry based model of the fragments, Gaussian splatting can offer enhanced detail. However, it was through the Blender-based reconstruction that a coherent hypothesis for the object's original use could be visualised. The historical research revealed that the fragments most likely formed the curtain panels and valances of a four-poster bed intended for 17th-century elite interiors.

Material analysis has substantiated these findings, as the presence of American cochineal and kermes, and possibly Armenian cochineal, indicated a textile that fit into the context of the wide-ranging Mediterranean trade networks

7.3 The Heiloo case and methodological transferability

The inclusion of the Heiloo fragments as a preliminary case study allowed for early testing of the modelling approach on a similarly fragmented textile set. Insights from this earlier study informed the final workflow for the BZN17 textiles. The approach to digitally reconstruct missing embroidery or structural components based on comparative liturgical garments could be adapted for this group of furnishing textiles of the BZN17 shipwreck. This shows that while fragment conditions vary, the core methodology—photogrammetry combined with gaussian splatting and the modelling of historically substantiated hypotheses—offers a versatile blueprint for future textile reconstructions.

7.4 Interdisciplinary and public engagement

This research also reinforces the broader role of digital reconstruction in enhancing both scholarly inquiry and public engagement. While traditional displays of textile fragments in vitrines often lack interpretive power, the 3D reconstructions created here offer a more holistic and educational experience. When combined with interactive platforms (such as a possible online viewer or annotations in the model), these digital artefacts bridge the gap between conservation priorities and public storytelling.

Furthermore, the application of digital heritage ethics—namely the London Charter and the

[94] Exporting all the models simply asked too much of my laptop, the modelling itself already took multiple hours per fragment. And the unpaid version of Postshot, the gaussian splatting software used, would not export the file.

Seville Principles—ensured that the visual outputs remained academically rigorous, distinguishing between what is observed, inferred, and imagined.

7.5 Limitations and setbacks

While meaningful progress has been made, several limitations affected the current stage of the reconstruction: these are factors such as environmental limitations, the limits of photogrammetry and gaussian splatting software, equipment quality and time constraints. Working in a depot basement limited lighting control, contributing to inconsistencies in exposure and model accuracy. And while Agisoft provided passable mesh models, fine threads and fringe or other details are not captured. The fact that textiles are usually flexible, which impacts the shape of the object when it is repositioned, prevented alignment of top and bottom models. Furthermore, although detailed close-ups were attempted, the camera setup was not able to consistently capture thread spacing with sufficient clarity. Stitching multiple macro images together using photoshop introduced alignment errors and noise. And last, he most important challenge was that the opportunity to photograph all fragments was constrained by access windows, impacting the quality of the captured data.

7.6 (To be) gained

Although not all ambitions of this project have been fulfilled, many important staps were taken to prove the value of an approach like this for (archaeological) heritage textile collections. Historical comparative research based on material characteristics and decoration provided a strong case for a possible original appearance of the group of fragments. The process also revealed how much physical deformation (folding, fraying, water warping) complicates visual puzzle-solving, but also how 3D modelling can help re-visualize those deformations. And the use of Gaussian splatting, though it is newer and less common in heritage contexts, proved surprisingly effective for showcasing surface detail and color integrity. Perhaps most significantly, this work confirms that even incomplete and degraded archaeological textiles can be meaningfully visualised and reconstructed — digitally and interpretively — when carefully documented.

Future attempts might benefit from a more time and different circumstances. And, as during this project, no algorithmic thread-based matching has been successfully performed due to image resolution limitations, future research could be aimed at using computer aided analysis to cluster, match and align archaeological fragments. This would add another layer of certainty to hypotheses based on historical research.

8. Conclusion

This thesis has explored the multifaceted challenge to find out what object are the BZN17 textile fragments are part of, and how would they originally would have looked. Through a combination of historical research, digital modelling techniques, and material analysis, a comprehensive and substantiated answer has emerged. Each part of this thesis has contributed essential building blocks toward understanding the fragments' origin, function, and appearance.

The chapter on the BZN17 case study laid the foundation by contextualizing the textile fragments recovered from the BZN17 shipwreck, also known as the Palmhoutwrak. The ship, a mid-17th-century merchant vessel, yielded one of the most significant maritime textile finds in Europe. The anaerobic conditions at the wreck site preserved silk textiles in an exceptional state. Among these were the crimson silk fragments at the center of this study. Their material properties and elite craftsmanship hinted at a high-status origin and an intended use within a domestic or ceremonial interior setting, rather than on-board ship functionality.

The chapter on the how and why of digital heritage reviewed the role of reconstructions in textile heritage. It emphasized that fragmented archaeological textiles are often unintelligible without interpretive aids. Digital reconstructions, particularly in the field of textile conservation, offer a non-invasive means to hypothesize original forms and to communicate this knowledge to broader audiences. The chapter concluded that reconstructions are not merely speculative exercises but powerful interpretive and preservation tools that allow fragmented objects to "speak" again.

The chapter that followed, provided an overview of state-of-the-art digital visualisation methods, including photogrammetry, Gaussian Splatting, and 3D modelling. Ethical principles such as the London Charter and the Seville Principles were foregrounded to guide the project in maintaining academic integrity. The chapter also explored the potential of AI and computational techniques to enhance or automate aspects of digital reconstruction. Importantly, it established the technological framework within which the BZN17 fragments could be responsibly and rigorously visualised.

The fifth chapter documented the methodology and processes of this project, as wel as a preliminary reconstruction of the Heiloo fragments, which served as a methodological test case. These fragments had already been identified as part of a chasuble. The case study allowed for trial-and-error in imaging and modelling techniques, establishing workflows that were later refined for the BZN17 project. It demonstrated that even incomplete textiles can yield meaningful visual hypotheses when guided by interdisciplinary methods.

In the attribution chapter, detailed historical and material analyses were conducted. Dye analysis identified rare combinations of American cochineal, kermes, and possibly Armenian cochineal—indicating access to Mediterranean and transatlantic trade networks. The silk's weave, embellishments, and dimensions aligned with 17th-century furnishing textiles. And systematic comparisons with inventories, visual sources, and surviving bed hangings support the hypothesis that these fragments once formed part of the curtain panels and valances of a four-poster bed—likely belonging to a wealthy individual involved in maritime commerce or diplomacy.

The last chapter synthesized the practical reconstruction work and drew conclusions about the implications of the object type. Using photogrammetry and Gaussian splatting, 3D models were created that document and preserve the fragments' shape and texture. Despite limitations (e.g., poor lighting, limited access to fragments), the modelling revealed important insights into how these techniques might be used in future textile heritage conservation efforts. Public and academic engagement potentials were also discussed, underscoring the value of such reconstructions beyond scholarly circles.

In conclusion, to answer the central research question, “What object are these textile fragments part of, and how would they have looked originally?”, the following has resulted from this research: The combined evidence presented in this thesis strongly supports the conclusion that the BZN17 textile fragments formed the curtain panels and valances of a seventeenth-century four-poster bed, most likely the possession of a person in elite cirlces. The ensemble would features rich crimson silk dyed with exotic insect-based dyes, demonstrating not only aesthetic refinement but also the owner's access to global trade networks. This contributes not only to our understanding of the fragments themselves, but also provides a lens into seventeenth-century material culture and interior design.

Considerations and future research

A major limitation was the environment in which data was captured—poor lighting and restricted access times led to lower image resolutions and inconsistencies in 3D models. Additionally, software limitations, particularly with photogrammetry and Gaussian splatting, posed challenges for capturing high leves of detail. Despite these setbacks, the thesis proved that even severely fragmented archaeological textiles can be meaningfully reconstructed, visually and interpretively.

The ambitions initially included reconstructing the object with annotations and an interactive element through animating the scanned models and the final reconstruction, they remain worthy of future pursuit. For example, an interactive model could enable museum visitors to "play" with the bed hangings themselves, with the possibility of deconstructing the object, showing how the fragments fit into it and how it would have been constructed, exploring the function and craftsmanship in an engaging and educational manner, or provide visual and textual information on their historical context. Another layer to this project could have been the use of computer aided thread analysis to provide even more evidence as to how the fragments could have fit together. Ideally, in a future model, the used sources (as images and text/citations) would be included as annotations that can be viewed in an interactive model. This would be the same for alternative hypotheses. Within the scope of this project this was not possible. According to best practices of digital heritage, for future projects a comprehensive technical report should be compiled, which includes detailed discussions of the software, reconstruction hypotheses, and annotated evidence.

This thesis exemplifies how digital reconstruction can serve as both a research methodology and a public storytelling tool, offering unprecedented access to fragmented and fragile textile heritage objects. By combining computational techniques, historical insight, and material analysis, it demonstrates a scalable methodology for reconstructing and understanding archaeological textiles.

The reconstructed bed hangings from the BZN17 wreck are not just digital hypotheses—they are windows into the domestic life, material wealth, and global networks of a seventeenth-century world, as the fragments in their current state are no longer able to convey their rich historical context. And ultimately, this case study can serve as a methodological model for future digital reconstructions of archaeological textiles. As digital tools continue to evolve[95], so too does our capacity to recover the stories of the past with nuance and accessibility. Further digitization of our society in years to come will undoubtedly impact the heritage sector as well. Even now, as AI is developing at a breakneck pace, machine learning and the use of algorithms continue to learn skills previously thought to be unique to human intelligence. The use of such tools might improve digital techniques for heritage preservation even more and streamline the still new and imperfect processes. As long as adequate academic guidelines can keep up with this rapid digital revolution, this new era will bring many more benefits to the (textile) conservation field.

[95] https://holburne-rti.vercel.app/about ; https://www.exhibit.so/

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10. Appendices

10.1 Object overview

All images courtesy of Huis van Hilde.

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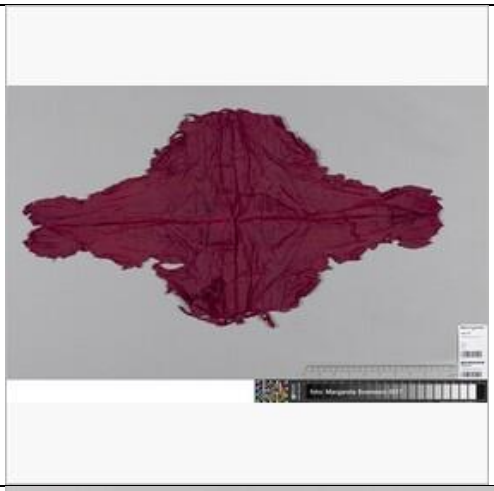
6263-002		
6263-030		

6263-051		
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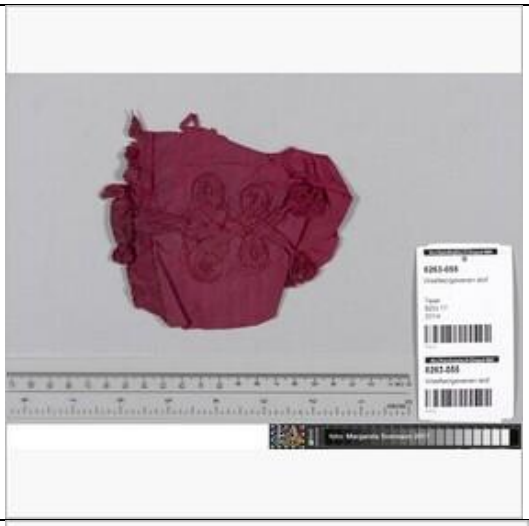
6263-055		
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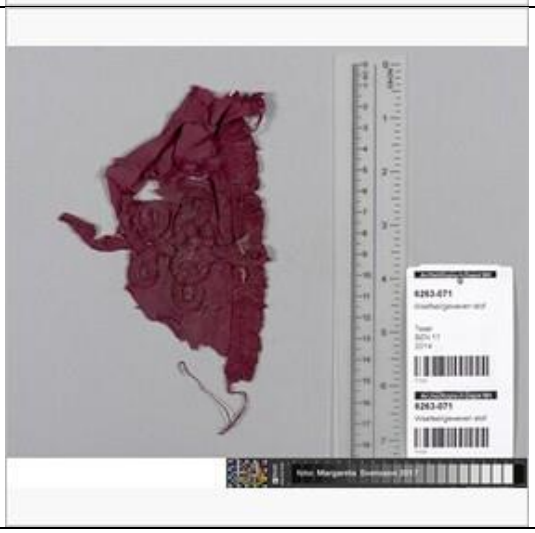
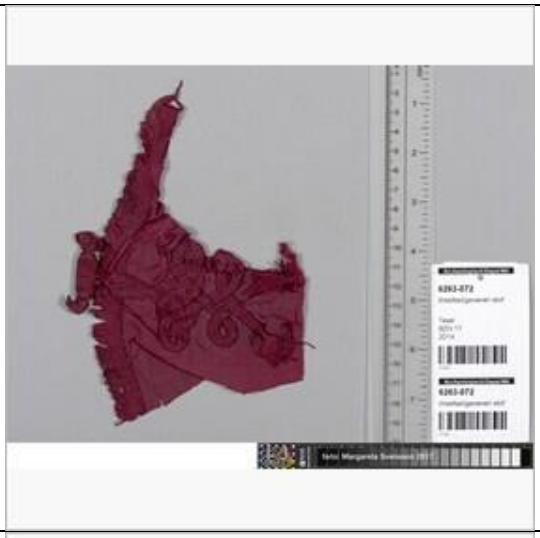
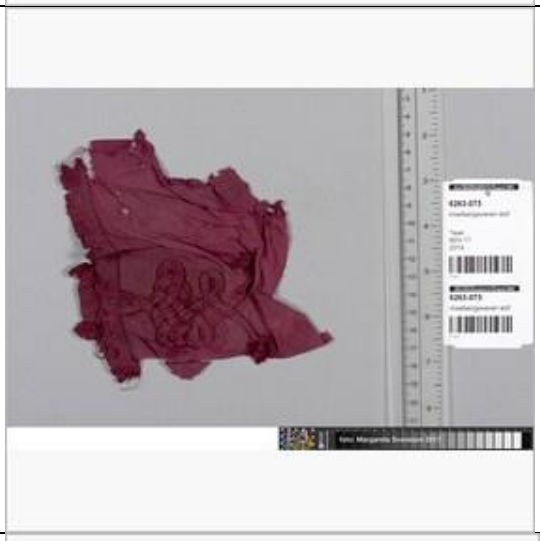
6263-071		

6263-072		
6263-073		
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6263-075		
6263-076		
6263-077		

6263-078	
6263-081	
6263-097	

6263-099	
6263-102	
6263-104	

6263-120	
6333-51	

Complete Panels

Fragment ID	Dimensions (cm)	Frog Fastenings	Special Features
6263-102	200W × 172H	8 female frogs on right and left sides	Bilateral symmetric damage, round reinforcements with stitches and tape at top, small fringe on bottom and sides, significantly lighter in colour, but same dye and material
6263-104	170H × 190-200W	8 male frogs on right and left sides	Stuck together with non-original material (from sea?) creating bow shape, round/tape reinforcements at top, small fringe on bottom and sides

Big Fragments

Fragment ID	Description	Dimensions (cm)	Notes
6263-051	Center piece of panel	70L × 36.5W	Folded twice, damaged while folded, diamond-shaped, double layer (two identical pieces)

Corner Pieces

Fragment ID	Position	Frog Details	Features
6333-51	Left bottom (probable)	Male frogs on left side	Fringe around edges
6263-030	Left top (probable)	3 male frogs on left side	Reinforcement strip remnants

Edge Pieces

Fragment ID	Frog Configuration	Edge Features	Notes
6263-052	3 sets male & female	Wide fringe on bottom	Two edges sewn together, fake closure?
6263-053	3 sets male & female	Wide fringe on bottom	Two edges sewn together, fake closure?
6263-054	None	Fringe only	-
6263-055	1 male	Edge with surrounding fabric	-
6263-056	1 male	Edge with surrounding fabric	-
6263-062	1 male	Edge with surrounding fabric	-
6263-069	1 male	Longer side edge trim	No surrounding fabric
6263-070	1 male	Edge with surrounding fabric	-
6263-071	1 female	Small fringe	-
6263-072	1 male	Edge with surrounding fabric	-
6263-073	1 male	Edge with surrounding fabric	-
6263-075	1 male	Side and edge trim	Extends to include side fabric piece
6263-077	1 male	Side and edge trim	Extends to include side fabric piece
6263-078	1 male	No edge	Surrounding fabric only
6263-081	3 sets male & female	Wide fringe on bottom	Two edges sewn together, fake closure?
6263-097	None	Long piece of wider fringe	No frogging
6263-099	1 male	Longer side edge trim	No surrounding fabric

Loose Frogging

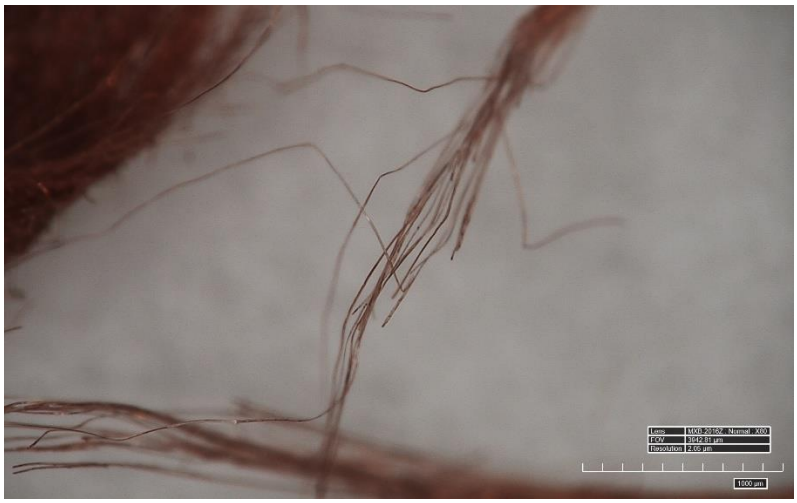
Type	Fragment IDs
Male	6263-002, 6263-066, 6263-076
Female	6261-015, 6261-001, 6263-063, 6263-064, 6263-065, 6263-067, 6263-068, 6263-074

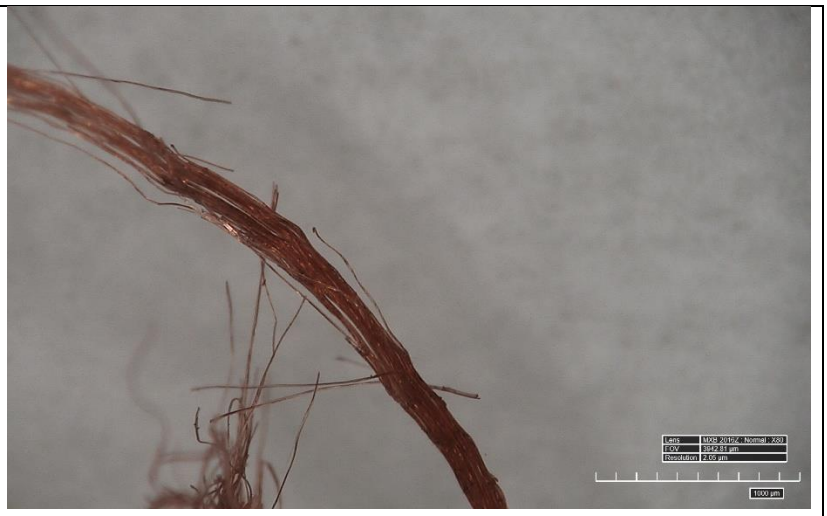
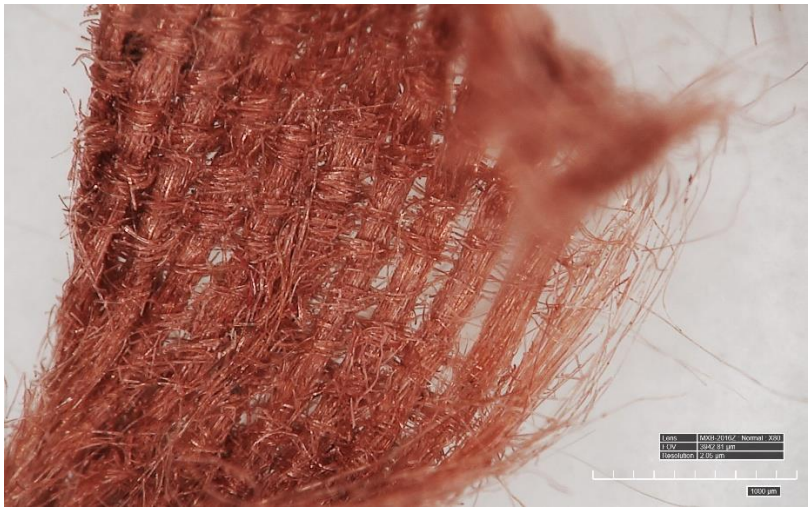
10.2 Scientific research form – BZN17 fragments

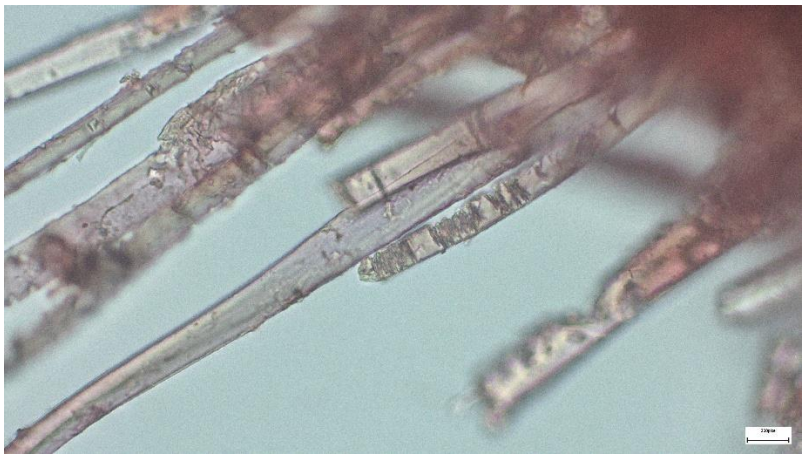
Title/type of object	BZN17 Fragments
Researcher	Noa Duijsens
Date of sampling	*12 February 2025*
Purpose of sampling	Determine fragmented textile materials and dyestuffs.
Sample number(s) and description	1. 6263-104, top left, “button” reinforcement 2. 6263-102, top left, tape 3. 6263-102, left middle, weft
Sample location 1	 
Sample location 2	  

Sample location 3	 
Results – Hirox, Sample 1	 

Results – Hirox, Sample 2	 

Results – Hirox, Sample 2	  

	 
Results – Microscopy Sample 1	 *Sample 33. 100X*

	 *Sample 1. 200x*
Results – Microscopy Sample 2	 *Sample 34. 200x*  *Sample 2. 500x*
Results – Microscopy Sample 3	(No microscopy done)

10.3 High performance liquid chromatography (by dr. Ana Albano Serrano)

Sample preparation

The samples were accurately weighted (circa 0.2 - 0.4mg). To extract the colourants from the textile samples presented here as a case study, a two-step extraction was performed according to the method of Serrano et al (2015):

Step 1) Each sample was extracted and placed in a 1 mL vial and extracted with 50 µL of a solution of 100% DMSO. The sample was placed in a heating block at 80ºC for 10 minutes. Afterwards, the liquid extracted was transferred into an insert. A residue of the fibre remained in the original vial.

Step 2) The fibre residue sample was further extracted with 50 µL of a solution of HCl:H2O:MeOH (2:1:1, v/v/v). The vial was placed in a heating block at 100ºC for 10 minutes.

After the extraction, the samples were evaporated to dryness under a gentle nitrogen flow . The dried extract was reconstituted with the previously obtained DMSO extract, mechanically agitated, and centrifuged for 10 minutes at 700 RPM with a tabletop centrifuge from VWR. The supernatant was then carefully transferred into a new insert for dye analyses.

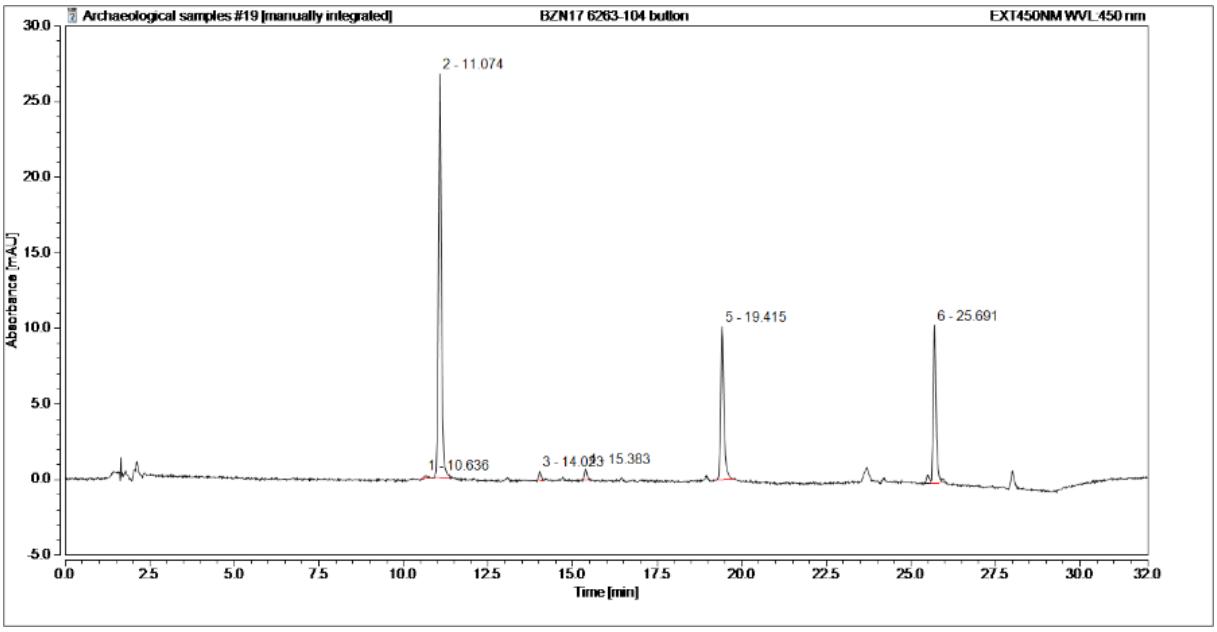
UHPLC-PDA

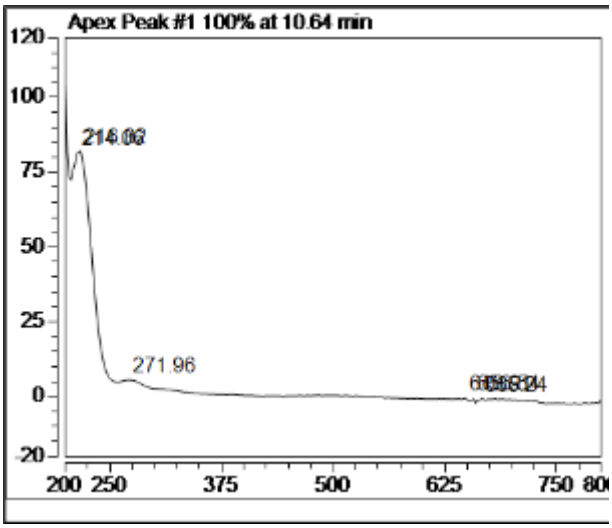
An ACQUITY ultra-high performance liquid chromatography (UHPLC) system H–class (Waters, Milford, MA, USA), consisting of a quaternary pump, autosampler, column oven, and a photodiode array detector (PDA), was used. The chromatographic separation was performed on a ZORBAX Eclipse Plus C13 2.1 x 150 mm, 1.8 µm column (Agilent Technologies).

The column oven and autosampler temperatures were kept at 40 °C and 15 °C, respectively. The analysis was performed at a flow rate of 0.2 mL/min, using gradient elution. The aqueous phase (solvent A) was prepared with 94.9:2.5:2.5:0.1 (v/v/v/v) H2O:MeOH:ACN:formic acid mixture containing 0.5 mM ammonium formate. The organic phase (solvent B) was prepared with 5:47.45:47.45:0.1 (v/v/v/v) H2O:MeOH:ACN:formic acid mixture containing 0.5 mM ammonium formate (Astefanei et al., 2025). The elution programme used by Astefanei et al was adapted to have a total run of 32 min: 0 – 1.0 min, isocratic gradient of 95A:5B (v/v); 1.0-3.5 min, linear gradient to 80A:20B (v/v); isocratic gradient until 5 min; 5.0-17 min, linear gradient to 40A:60B (v/v); isocratic gradient until 19 min; 19-24 min, linear gradient to 5A:95B (v/v); isocratic gradient until 26 min; 26-27 min, linear gradient 95A:5B (v/v); isocratic gradient until 32 min.

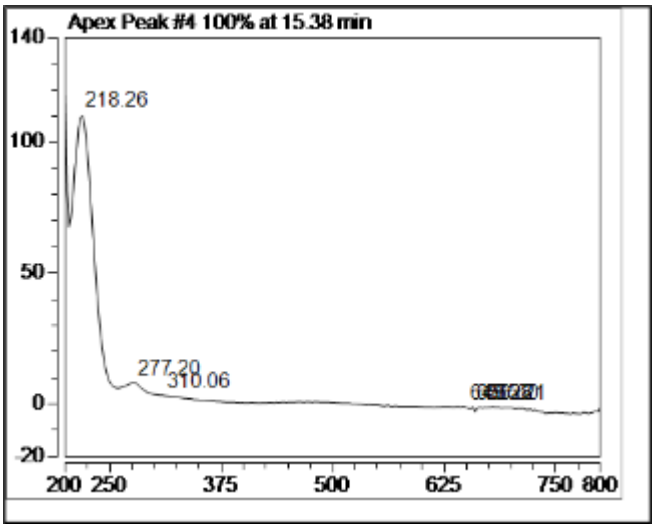
6263-104 'button':

Compounds detected: dcII, CA, dcIV, dcVII, KA
Attribution: Cochineal and kermes

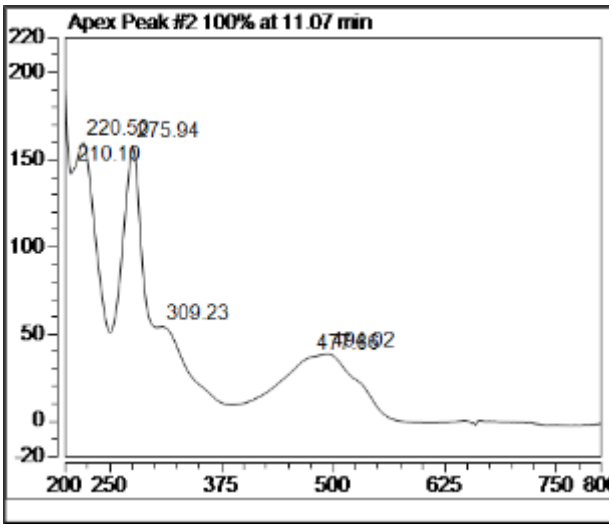




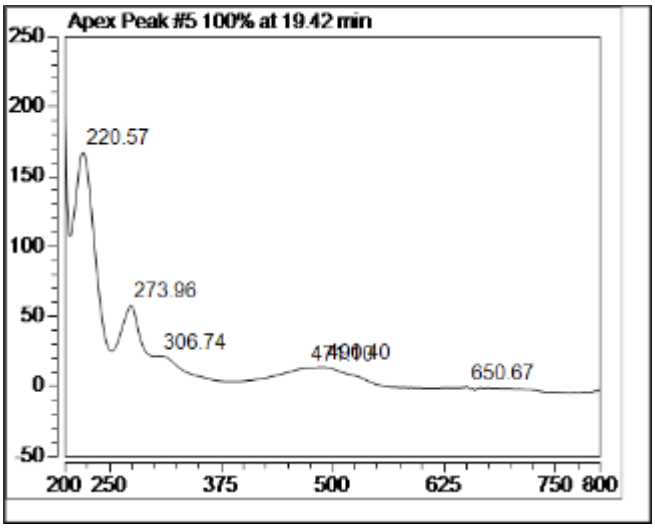
dcII



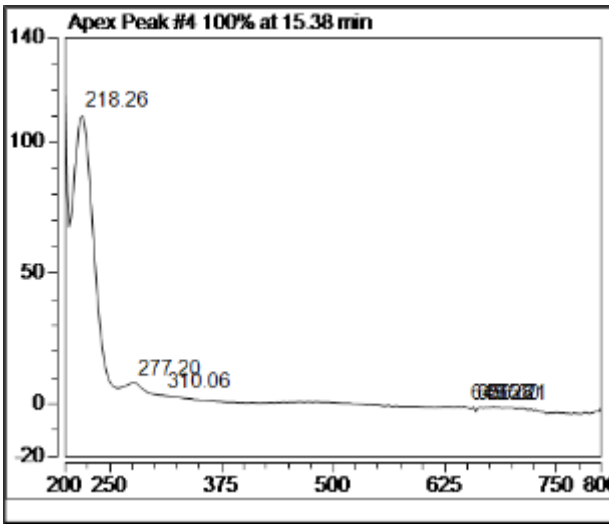
dcVII



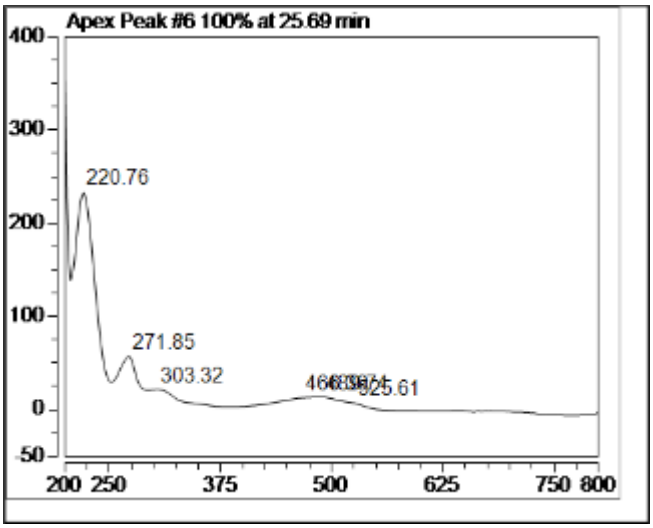
carminic acid



kermesic acid



dcIV

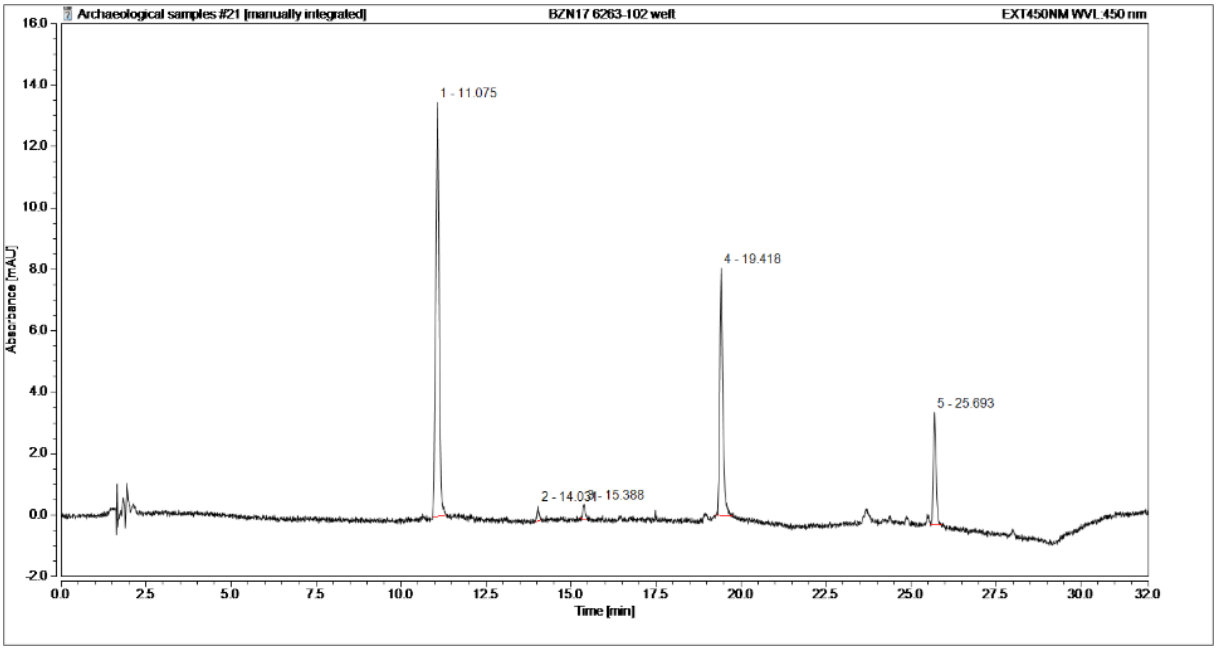


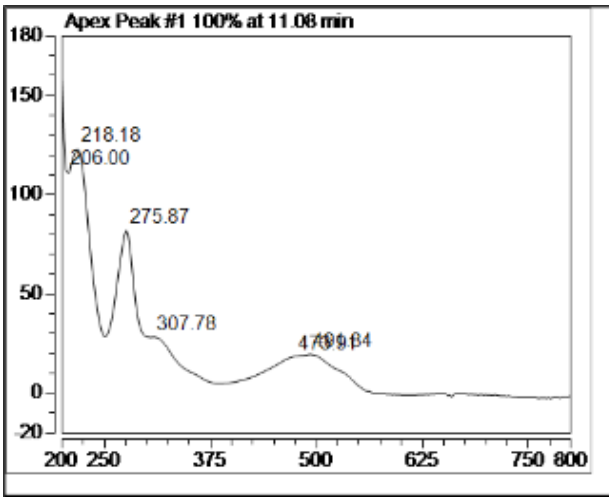
kermesic acid equivalent

6263-102 weft:

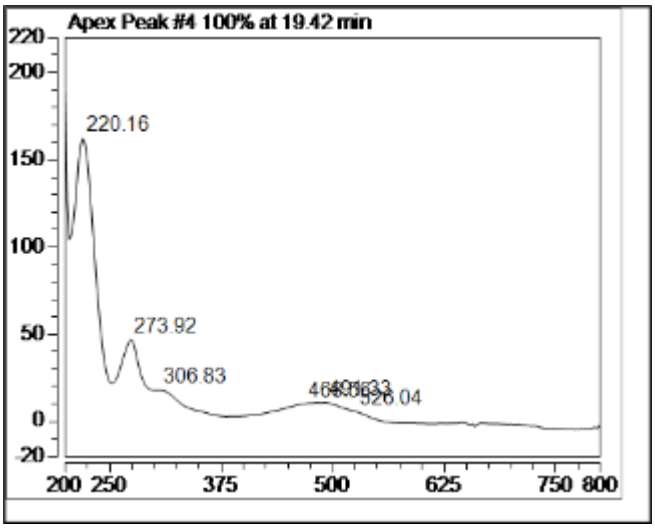
6263-102
1. tape
2. warp and weft

Compounds detected: CA, dcIV, dcVII, KA
Attribution: Cochineal and kermes

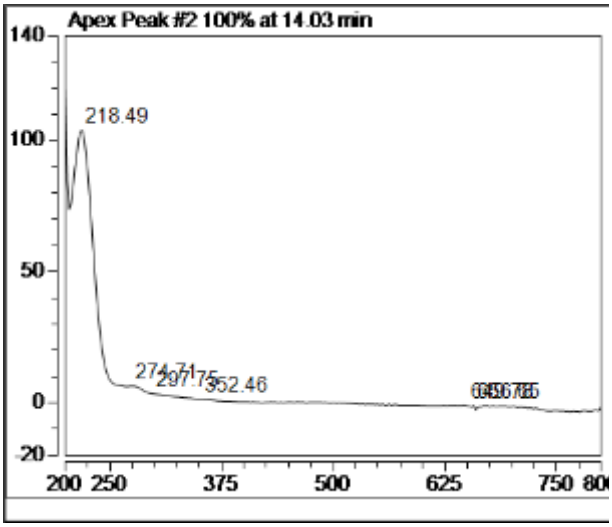




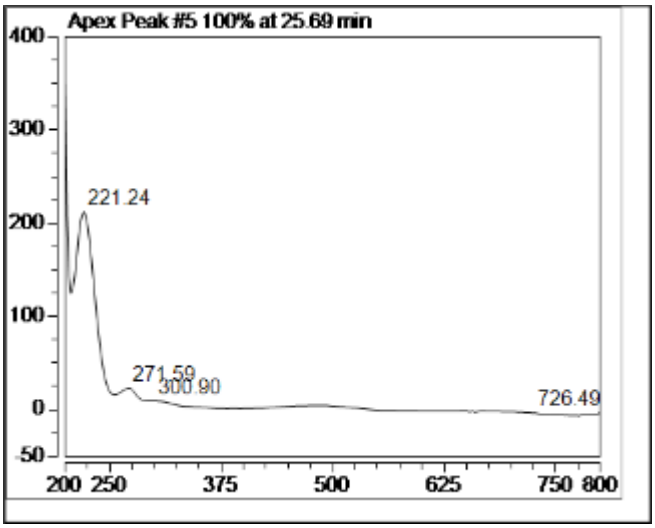
Carminic acid



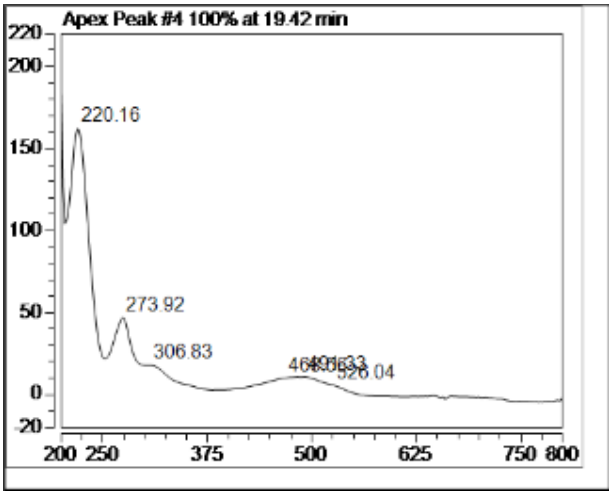
kermesic acid



dcIV



kermesic acid equivalent



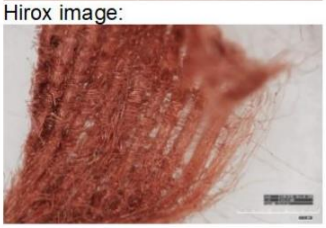
dcVII

10.4 SEM-EDX (by dr. Ana Albano Serrano)

Analyses were carried out with a SEM-EDX Jeol IT700HR using 20 kV accelerating voltage, 10 mm working distance, and backscattered signal (BED-S) at low vacuum (30 Pa). EDX measurements were done with 30 seconds acquisition time.

Sampling	Dye analyses	Fibre/metal characterization
1. Button reinforcement  Hirox image: 	Sample weight: 0. mg ask Rian Compounds detected: dcII, CA, dcIV, dcVII, KA Dyestuff attribution: Cochineal and kermes Date of analysis: 26/05/2025	Transmitted light microscopy: silk – smooth and cylindrical surface, occasional faint striations, very damaged, surface dirt SEM-EDX: Silk fibres, some areas of the sample more damaged than others; obvious signs of pitting and areas with collapsed fibres. Some crystals and large silver sulphide residues attached to the fibres. Small peaks of sodium, magnesium, calcium, aluminium (mordant?), on the fibres' surface; carbon, oxygen, sulphur and nitrogen from the fibres. Date of analysis: 12/06/2025

6263-102
1. tape
2. warp and weft

Sampling	Dye analyses	Fibre/metal characterization
1. Tape  Hirox image: 	Sample weight: 0. mg ask Rian Compounds detected: none Dyestuff attribution: Inconclusive results Date of analysis: 26/05/2025	Transmitted light microscopy: silk – smooth and cylindrical surface, occasional faint striations, long, damaged (pitting) and surface dirt SEM-EDX: not analysed
2. Warp and weft  Hirox image: 	Sample weight: 0. mg ask Rian Compounds detected: dcII, CA, dcIV, dcVII, KA Dyestuff attribution: Cochineal and kermes Date of analysis: 26/05/2025	Transmitted light microscopy: not performed SEM-EDX: Weave clearly shows how broken the weft threads are (thinner than the warp). All made of silk fibres; obvious signs of pitting and some collapsed fibres; moderately clean (very few crystals and silver sulphide residues). Small peaks of sodium, magnesium, calcium, aluminium (mordant?), on the fibres' surface; carbon, oxygen, sulphur and nitrogen from the fibres. Date of analysis: 12/06/2025

10.5 Fragment condition reports (courtesy of Huis van Hilde)[96]

10.5.1

Gegevens object

Object	4 grote fragmenten + 22 kleine fragmenten
Afbeelding	BZN17-01; BZN 17-02; BZN17-31 BZN17-53; BZN-54; BZN17-56; BZN17-57; BZN17-67 t/m 85; BZN17-87; BZN17-104   Afb.1 Inv.nr. 081, Foto Kaap Skil Afb.2 Inv.nr. 056, Foto Kaap Skil
Inventarisnummer	001 002 030 052 053 055 056 062 063 064 065 066 067 068 069 070 071 072 073 074 075 076 077 078 081 99
Beheer	Museum Kaap Skil, Texel
Context	Textiel uit scheepswrak BZN17 Palmhoutwrak, ca.1640, vondst Waddenzee 2014
Contactpersonen	Maarten Roeper 0222-314956, maarten@kaapskil.nl Corina Hordijk, 0222-314956/06-24552184, CorinaHordijk@kaapskil.nl
Beschrijver	Sjoukje Telleman, UvA, sjoukje_telleman@hotmail.com Marijke de Bruyne, UvA, mdebruyne@hetnet.nl
Begeleiding	Emmy de Groot, Maarten van Bommel, UvA

Beschrijving

Korte beschrijving	Rood basisweefsel van zijde, in platbinding. Onbekend waar de fragmenten voor hebben gediend. De fragmenten zijn versierd met tressen van rood koord. De tressen zijn voorzien van een knoop of lus, zodat ze kunnen fungeren als sluiting. Een aantal van de kleinere fragmenten bestaat enkel nog uit tressen met snippers basisweefsel. De vier grote objecten (081; 052; 030; 053) hebben korte (0.5 cm) of lange (6,5 cm) franje randen	
Afmetingen	1 tres met knoop: 11,5 bij 6 cm (hxb) 030: (incl. korte franje) 20 x 75 cm 052: (incl. lange franje) 33 x 56 cm 053: 36 x 28 cm 081: (incl. lange franje) 35 x 34 cm	
Vorm	Onregelmatig	
Materiaal	x	Zijde (basis materiaal; koord/tres is niet zeker)
		Wol
		Katoen
		Linnen
		Overig, nl.
Techniek	Basismateriaal in platbinding. Opgenaaide tressen van gevlochten koord; franjes	
Kleur	Paarsachtig rood	
Constructie	030: een lap met 3 tressen met knopen op ongeveer 21 cm van elkaar, langs een rand met korte franjes. Eén van de korte uiteindes heeft een zoom.	

[96] Not all fragments that are part of this group have a condition report, the exceptions are: 6333-50, 6333-51 and 6261-015.

	052/053/081: de tressen vormen met knopen en lussen een schijnsluiting. De passementen zijn op een doorlopend stuk basismateriaal genaaid. Dwars op de schijnsluiting zijn lange franjes aangebracht. Van de 22 fragmenten bestaan 8 fragmenten alleen uit losse tressen. Aan 077 en 056 zit nog het meeste basisweefsel, vergelijkbaar met 030. De overige fragmenten zitten hier tussenin	
Bijzonderheden		Weefsel: binding, patronen, motieven:
	x	Sluitsysteem (knoopjes, haakjes, e.d.): schijnsluiting
		Randafwerkingen, passementen etc.:
		Versieringstechnieken:
		Materiaal:
		Voering:
		Naden, sporen van naaisels:
	x	Anders, nl. zelfde tressen gebruikt op object 102, maar lijken toch niet bij elkaar te horen. Ondermeer andere kleur. Zie ook inv.nrs. 051, 054/097 en 104

Conditie

Conditiebeschrijving	Slecht. scheuren in de stof en delen van het basisweefsel ontbreken. Er is relatief veel verlies van vezels zichtbaar. De basisstof is redelijk soepel en het vlechtwerk is in goede conditie. Het basisweefsel verdwijnt terwijl het vlechtwerk overblijft.	
Vuil	x	Wat zand, maar relatief schoon. Met name de franjes zijn stijf en zitten vol vuil.
Vervormd	x	053 is heel erg vervormd
Degradatie	x	Veel vezelverlies
Verkleuring	x	Met name op 052 zitten opvallende zwarte vlekken. 081 heeft ook enkele zwarte vlekken
Mechanische schade		Draagsporen?
		Anders, nl.
Biologische schade		Nee
Verlies	x	
Overig		
Algemeen oordeel		Goed
		Matig
	x	Slecht
Bijzonderheden	Opvallend is dat de fragmenten nog een mooie diep rode/paarse kleur hebben	

Onderzoek

Algemeen	Wat is de functie van het object/objecten, waar zijn de fragmenten van? Is het originele object te reconstrueren? Vormen alle lossen fragmenten wel 1 object (030 versus 053/053/081)? Dienden de tressen daadwerkelijk als sluiting? Waar zijn de tressen van gemaakt? Relatie met andere objecten?	
Monstername	Nummer	Monster nr. 13
Soort onderzoek	Natuurwetenschappelijk:	
	x	Materiaal/vezelonderzoek: materiaal van de tressen
		Samenstelling
	x	Conditie
	x	Kleuronderzoek: ook vergelijken met 102
	Ander:	
		Historisch
	x	Kunsthistorisch
	x	Constructie, maakproces, patroon
	x	Overig, nl. vergelijken met andere objecten uit de collectie, inv.nrs. 051 en 054/097, 102, 104

Selectie voor verder onderzoek

Ja	x	077 en 081
Nee		
Misschien		
Opmerkingen	077 is vergelijkbaar met object 030; zo kan gekeken worden of deze fragmenten van het zelfde object zijn	
Uiteindelijke selectie	Ja, object 077	

Foto's

Afb.3 'Schijnsluiting'

Afb.4 Zwarte vlekken

Afb. 5 Detail knoop object 077, vergroting: x7,5

10.5.2

Gegevens object

Object	1 fragment, bestaande uit 2 delen
Afbeelding	BZN17-52

	 Afb.1 Foto Museum Kaap Skil
Inventarisnummer	051
Beheer	Museum Kaap Skil, Texel
Context	Textiel uit scheepswrak BZN17 Palmhoutwrak, ca.1640, vondst Waddenzee 2014
Contactpersonen	Maarten Roeper 0222-314956, maarten@kaapskil.nl Corina Hordijk, 0222-314956/06-24552184, CorinaHordijk@kaapskil.nl
Beschrijver	Sjoukje Telleman, UvA, sjoukje_telleman@hotmail.com Marijke de Bruyne, UvA, mdebruyne@hetnet.nl
Begeleiding	Emmy de Groot, Maarten van Bommel, UvA

Beschrijving

Korte beschrijving	1 fragment van een rood weefsel in platbinding, 2 delen in precies gelijke vorm op elkaar	
Afmetingen	36,5 x 70 cm	
Vorm	Een soort vierpas, in het midden 2 vouwen. Mogelijk origineel een vierhoek	
Materiaal	x	Zijde (basis materiaal; koord/tres is niet zeker)
		Wol
		Katoen
		Linnen
		Overig, nl.
Techniek	Platbinding	
Kleur	Paarsachtig rood	
Constructie	-	
Bijzonderheden		Weefsel: binding, patronen, motieven:
		Sluitsysteem (knoopjes, haakjes, e.d.): schijnsluiting
		Randafwerkingen, passementen etc.:
		Versieringstechnieken:
		Materiaal:
		Voering:
	x	Naden, sporen van naaisels:
	x	Anders, nl.: weefsel en kleur lijkt op inv.nr. 030 etc. maar zonder tressen

Conditie

Conditiebeschrijving	Matig, beschadiging langs 4 randen is precies symmetrisch, moet zijn opgetreden terwijl het object was opgevouwen	
Vuil		
Vervormd		
Degradatie	x	Enigszins vezelverlies
Verkleuring		
Mechanische schade		Draagsporen?
		Anders, nl.
Biologische schade		Nee

Verlies	x	
Overig		
Algemeen oordeel		Goed
	x	Matig
		Slecht
Bijzonderheden	Opvallend is dat de fragmenten nog een mooie diep rode/paarse kleur hebben	

Onderzoek

Algemeen	Wat is het geweest? Kussensloop? Is het object te relateren aan andere objecten in de collectie?	
Monstername	Nummer	
Soort onderzoek	Natuurwetenschappelijk:	
		Materiaal/vezelonderzoek: materiaal van de tressen
		Samenstelling
	x	Conditie
	x	Kleuronderzoek: vergelijken met 102 en 030
	Ander:	
		Historisch
	x	Kunsthistorisch: functie
		Constructie, maakproces, patroon
	x	Overig, nl.: vergelijken met andere objecten in de collectie, nl. inv.nrs. 030 etc., 054/097 en 102

Selectie voor verder onderzoek

Ja		
Nee	x	
Misschien		
Opmerkingen		
Uiteindelijke selectie	nee	

Foto's

Afb. 2 Delen in precies dezelfde vorm op elkaar, symmetrisch beschadigd

10.5.3

Gegevens object

Object	2 fragmenten
Afbeelding	BZN17-55, BZN17-102

	 Afb.1 Inv.nr. 054, Foto Kaap Skil  Afb.2 Inv.nr. 097, Foto Kaap Skil
Inventarisnummer	054 097
Beheer	Museum Kaap Skil, Texel
Context	Textiel uit scheepswrak BZN17 Palmhoutwrak, ca.1640, vondst Waddenzee 2014
Contactpersonen	Maarten Roeper 0222-314956, maarten@kaapskil.nl Corina Hordijk, 0222-314956/06-24552184, CorinaHordijk@kaapskil.nl
Beschrijver	Sjoukje Telleman, UvA, sjoukje_telleman@hotmail.com Marijke de Bruyne, UvA, mdebruyne@hetnet.nl
Begeleiding	Emmy de Groot, Maarten van Bommel, UvA

Beschrijving

Korte beschrijving	2 fragmenten van een rood weefsel, met langs 1 zijde passementen met lange franjes	
Afmetingen	054: 17 x 66 cm 097: 12 x 59 cm	
Vorm	2 lange smalle rechthoekige fragmenten, met langs 1 lange zijde passementen met lange franje	
Materiaal	x	Zijde (basis materiaal; koord/tres is niet zeker)
		Wol
		Katoen
		Linnen
		Overig, nl.
Techniek	Platbinding. Opgenaaide passementen met lange franjes	
Kleur	Paarsachtig rood	
Constructie	Opgenaaide franjes	
Bijzonderheden		Weefsel: binding, patronen, motieven:
		Sluitsysteem (knoopjes, haakjes, e.d.): schijnsluiting
		Randafwerkingen, passementen etc.:
		Versieringstechnieken:
		Materiaal:
		Voering:
	x	Naden, sporen van naaisels:
	x	Anders, nl.: lijkt op 030 etc. maar zonder tressen

Conditie

Conditiebeschrijving	Matig. Franjes vervormd, hard. 097 is bijna alleen nog franje, weinig basisweefsel over	
Vuil	x	Franjes vuil
Vervormd	x	Franjes vervormd
Degradatie	x	Veel vezelverlies
Verkleuring	x	Wat zwarte vegen en vlekken
Mechanische schade		Draagsporen?
		Anders, nl.
Biologische schade		Nee
Verlies	x	

Overig		
Algemeen oordeel		Goed
	x	Matig
		Slecht
Bijzonderheden	Opvallend is dat de fragmenten nog een mooie diep rode/paarse kleur hebben	

Onderzoek

Algemeen	Wat is de functie van het object/objecten, waar zijn de fragmenten van? Relatie met andere objecten?	
Monstername	Nummer	
Soort onderzoek	Natuurwetenschappelijk:	
		Materiaal/vezelonderzoek: materiaal van de tressen
		Samenstelling
	x	Conditie
	x	Kleuronderzoek: ook vergelijken met 102 en 030
	Ander:	
		Historisch
	x	Kunsthistorisch
	x	Constructie, maakproces, patroon
	x	Overig, nl.: vergelijken met andere objecten uit de collectie, nl. inv.nrs. 030 etc., 051, 102

Selectie voor verder onderzoek

Ja		
Nee	x	
Misschien		
Opmerkingen		
Uiteindelijke selectie	nee	

Foto's

Afb. 3Naaisporen, object 054

Afb. 4 vuil in de franje, object 054

10.5.4

Gegevens object

Object	Lap
Afbeelding	BZN17-110

	 Afb.1 Foto Museum Kaap Skil
Inventarisnummer	102
Beheer	Museum Kaap Skil, Texel
Context	Textiel uit scheepswrak BZN17 Palmhoutwrak, ca.1640, vondst Waddenzee 2014
Contactpersonen	Maarten Roeper 0222-314956, maarten@kaapskil.nl Corina Hordijk, 0222-314956/06-24552184, CorinaHordijk@kaapskil.nl
Beschrijver	Sjoukje Telleman, UvA, sjoukje_telleman@hotmail.com Marijke de Bruyne, UvA, mdebruyne@hetnet.nl
Begeleiding	Emmy de Groot, Maarten van Bommel, UvA

Beschrijving

Korte beschrijving	Rechthoekige lap met aan 2 korte zijden tressen, aan 3 zijden passementen met korte franjes	
Afmetingen	172 hoog x 200 cm breed	
Vorm	Rechthoekige lap	
Materiaal	x	Zijde
		Wol
		Katoen
		Linnen
		Overig, nl.
Techniek	Opgnaaide tressen en passementen	
Kleur	Rozerood	
Constructie	Verticale naad in het midden	
Bijzonderheden		Weefsel: binding, patronen, motieven:
		Sluitsysteem (knoopjes, haakjes, e.d.):
		Randafwerkingen, passementen etc.:
	x	Versieringstechnieken:
		Materiaal:
		Voering:
		Naden, sporen van naaisels:
	x	Anders, nl. tressen zijn identiek aan de tressen op 030 etc. De weefsels van het basisweefsel hebben echter een geheel andere uitstraling, 102 heeft veel meer glans dan 030 en de kleuren zijn ook zeer verschillend: 102 is roze-achtig, 030 is diep paarsachtig rood. Het zijn wel beide platbindingen. De tressen op 030 met de knoopjes hebben een onderlinge afstand van 24 cm, bij object 102 is de onderlinge afstand van de lusjes cm 21 a 22 cm. Hoewel de objecten dus bij elkaar lijken te horen, is dit waarschijnlijk niet het geval Ander vergelijkbaar object: inv.nr. 104 (lap met tressen en passementen) Ander vergelijkbaar object, maar zonder tressen: inv.nr. 051 en inv.nrs. 054 en 097

Conditie

Conditiebeschrijving	Slecht. Grote scheuren en gaten. Dun en fragiel. Weinig vezelverlies, dus toestand lijkt stabiel	
Vuil		

Vervormd	x	Vouwen. Schade ook op de vouwen
Degradatie		
Verkleuring		
Mechanische schade		Draagsporen?
	x	Overig, nl. gespiegelde scheuren en gaten. Is ontstaan terwijl het opgevouwen was
Biologische schade		
Verlies	x	
Overig		
Algemeen oordeel		Goed
	x	Matig
	x	Slecht
Bijzonderheden		

Onderzoek

Algemeen	Wat is het voor object? Wat was de functie?		
Monstername	Nummer	Monster 12	
Soort onderzoek	Natuurwetenschappelijk:		
		Materiaal/vezelonderzoek	
		Samenstelling	
	x	Conditie:	
	x	Kleuronderzoek: vergelijken met 030 etc.	
	Ander:		
		Historisch:	
	x	Kunsthistorisch: functie	
		Constructie, maakproces, patroon:	
	x	Overig, nl.: vergelijken met andere objecten uit de collectie, nl. inv.nrs. 030 etc., 051, 054/097, 104	

Selectie voor verder onderzoek

Ja		
Nee	x	Voorlopig alleen monstername
Misschien		
Opmerkingen		
Uiteindelijke selectie	nee	

Foto's

Afb.2 Inv.nr. 102 (boven) en inv.nr. 077 (onder)

Afb.3 Inv.nr. 102 (boven) en inv.nr. 077 (onder)

10.5.5

Gegevens object

Object	Lap

Afbeelding	BZN17-112, BZN17-113  Afb.1 Foto Museum Kaap Skil
Inventarisnummer	104
Beheer	Museum Kaap Skil, Texel
Context	Textiel uit scheepswrak BZN17 Palmhoutwrak, ca.1640, vondst Waddenzee 2014
Contactpersonen	Maarten Roeper 0222-314956, maarten@kaapskil.nl Corina Hordijk, 0222-314956/06-24552184, CorinaHordijk@kaapskil.nl
Beschrijver	Sjoukje Telleman, UvA, sjoukje_telleman@hotmail.com Marijke de Bruyne, UvA, mdebruyne@hetnet.nl
Begeleiding	Emmy de Groot, Maarten van Bommel, UvA

Beschrijving

Korte beschrijving	Waarschijnlijk rechthoekige rode lap met aan 2 lange zijden tressen, aan 3 zijden passementen met korte franjes	
Afmetingen	ca. 170 x 75,5 cm breed (NB: de breedte is gemeten in de huidige toestand, de originele breedte is niet op te meten door aangekoekte delen)	
Vorm	Rechthoekige lap, in het midden zijn de verschillende zijden aan elkaar gekoekt, waardoor het de vorm van een strik *lijkt* te hebben	
Materiaal	x	Zijde
		Wol
		Katoen
		Linnen
		Overig, nl.
Techniek	Opgenaaide tressen en passementen	
Kleur	Paarsrood	
Constructie	Aan 3 zijden passementen met franjes, aan de 4de zijde een zoompje. Op regelmatige afstand van ca. 8 a 9 cm op de zoom zitten restjes grof weefsel, van een voering en/of van een bevestigingssysteem? Het geheel heeft 2 naden en bestaat uit 3 banen, de buitenste ca. 54 cm, de middelste ca. 57 cm	
Bijzonderheden		Weefsel: binding, patronen, motieven:
		Sluitsysteem (knoopjes, haakjes, e.d.):
	x	Randafwerkingen, passementen etc.:
	x	Versieringstechnieken: tressen
		Materiaal:
		Voering:
		Naden, sporen van naaisels:
	x	Anders, nl. tressen zijn identiek aan de tressen op 030 etc. en 102. Qua vorm lijkt het object op inv.nr. 102, maar opvallend is de geheel andere uitstraling van het weefsel en de kleur. Kleur en uitstraling van het weefsel komen meer overeen met 030 etc. Het zou kunnen dat het daarbij hoort. De afstand tussen de tressen is ca 22 à 23 cm (bij 030 etc.: 24 cm; bij 102: 21/22 cm)

Conditie

Conditiebeschrijving	Slecht. Grote scheuren en gaten. Dun en fragiel. Zwarte plakken en aankoeksels, keihard. Zwarte afdrukken (waarschijnlijk corrosie) in de vorm van cirkels. Tressen zijn geplet, vies, hard	
Vuil	x	Zeer
Vervormd	x	Zeer
Degradatie	x	
Verkleuring	x	Zwarte afdrukken
Mechanische schade		Draagsporen?
Biologische schade		
Verlies	x	
Overig		
Algemeen oordeel		Goed
	x	Matig
	x	Slecht
Bijzonderheden	Opvallend: tressen in veel slechtere staat dan bij 030 etc. en 102	

Onderzoek

Algemeen	Wat is het voor object? Wat was de functie? Hoe is het object gerelateerd aan inv.nrs. 030 etc. en 102? Wat is de herkomst van de zwarte aankoeksels? Wat is de herkomst van de zwarte afdrukken in de vorm van cirkels; zijn deze te relateren aan de metalen ringen uit inv.nr. 105 rode damast 'gordijn'? Waardoor zijn de tressen in zoveel slechtere staat dan in inv.nrs. 030 etc. en 102?	
Monstername	Nummer	Monster 22 van de 'voeringresten' op de zoom Monster 23 van een zwart geworden vezels
Soort onderzoek	Natuurwetenschappelijk:	
	x	Materiaal/vezelonderzoek: aankoeksels ook
		Samenstelling
	x	Conditie: verschil in conditie tussen vergelijkbare objecten, tressen m.n.
	x	Kleuronderzoek: vergelijken met inv.nrs. 030 etc. en 102
	Ander:	
		Historisch:
	x	Kunsthistorisch:
		Constructie, maakproces, patroon:
	x	Overig, nl. vergelijken met andere objecten uit de collectie, m.n. met inv.nrs. 030 etc. en 102 (zelfde tressen en passementen) en inv.nr. 105 (met metalen ringen)

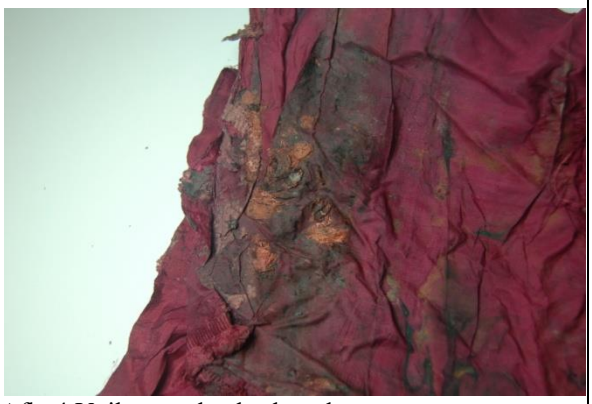
Selectie voor verder onderzoek

Ja		
Nee	x	Voorlopig alleen monstername
Misschien		
Opmerkingen		
Uiteindelijke selectie	nee	

Foto's

Afb. 2 Door een zwarte plak aankoeksel wordt de stof in het midden bijeen gehouden. Ook zijn corrosie afdrukken te zin (ringvormig)

Afb. 3 Resten van voering en aanwezigheid van een grof weefsel op regelmatige afstand van elkaar



Afb. 4 Vuil en aankoeksel op de tressen