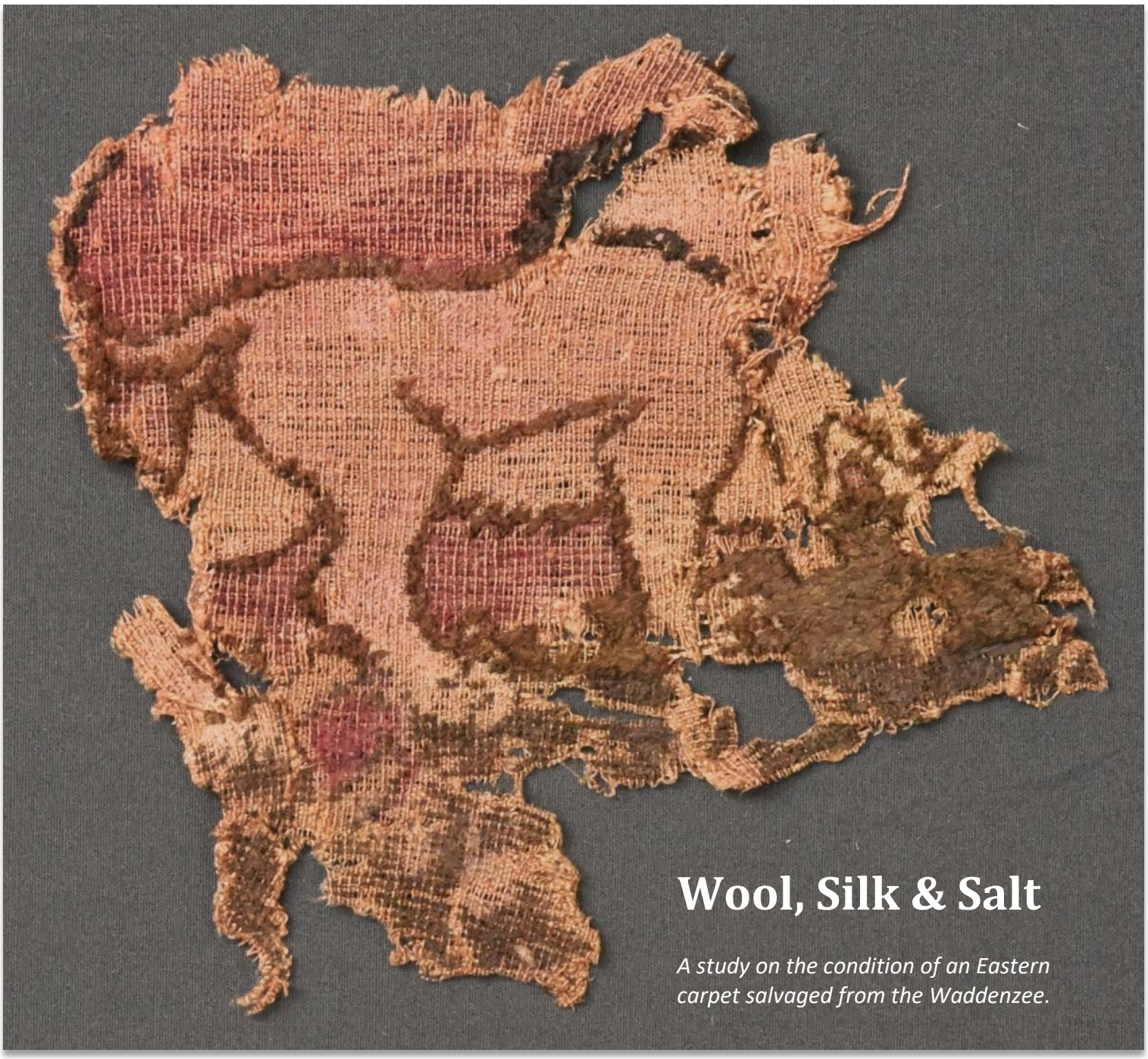


Wool, Silk & Salt

A study on the condition of an Eastern carpet salvaged from the Waddenzee.

Master's Thesis, University of Amsterdam

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Frontispiece: fragment IV, front side. Photo by author.

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Abstract

Wool, Silk & Salt. A study on the condition of an Eastern carpet salvaged from the Waddenzee.
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In the summer of 2014 thirteen fragments of a carpet were discovered in shipwreck BZN17 near the island of Texel, the Netherlands. The general condition of the fragments was poor: the fibres had become brittle, much of the pile was missing, colours had faded, and there was much contamination. Compared to the silk objects found in the same shipwreck, the carpet was in a much worse state. The focus of this thesis is to explain this difference in condition by examining the different factors that have contributed to the carpet's current state.

Previous research on the object using SEM-EDX and UHPLC had established the materials and dyestuffs used in the manufacture of the carpet. The ground weave was found to be made of silk, and the pile of wool and some metal thread. As dyestuffs indigo or woad, lac-dye and tannins were found. A literature review was done to gather information about the origin of the carpet, the common practices in marine archaeology and how these methods would influence to object's condition. Based on the design and colours of the carpet its origin was estimated to be in the second half of the 16th or early 17th century in eastern Persia.

From an interview with the diver who salvaged the carpet information could be gathered about the treatment of the object. It is possible that the carpet has been pulled apart during the salvage. Some of the pieces were rinsed and dried immediately, some the day after, and some were left to soak for a week. All were rinsed in tap water.

An assessment of the condition of each fragment was done, paying attention to colour, contamination, and remaining pile. The factors that may have contributed to the condition of the fragments were then examined. The treatment during and after the salvage could be directly related to the condition of each fragment. This was therefore established as the most important contributing factor. Material properties of the carpet and underwater conditions were found to be of secondary importance.

Lastly attack by marine bacteria was considered as a possible cause for the wool's poor condition. *Actinobacteria* produce keratinase: an enzyme which deteriorates wool fibres. These bacteria are commonly found in the topmost sediment layers of the ocean. While speciess of *Desulfovibrio* exist that may use amino acids directly, these sulphate-reducing bacteria have not been proven to inhabit the Waddenzee. Fermenting bacteria such as the *Actinobacteria* are therefore more likely to have been a contributing factor to the poor condition of the BZN17 carpet.

Keywords: Persian carpet, marine archaeology, fibre degradation, condition assessment, rinsing, drying, sulphate-reducing bacteria, SEM-EDX

Samenvatting

Wol, Zijde & Zout. Een onderzoek naar de conditie van een Oosters tapijt opgedoken uit de Waddenzee.

In de zomer van 2014 zijn er dertien fragmenten van een tapijt ontdekt in scheepswrak BZN17 vlakbij Texel, Nederland. De algehele conditie van de fragmenten was slecht: de vezels waren bros geworden, een groot deel van de pool was verdwenen, kleuren waren verbleekt, en de fragmenten waren sterk vervuild. Vergeleken met de zijden objecten die in hetzelfde wrak waren gevonden was het tapijt in een veel slechtere toestand. De focus van deze thesis is het vinden van een verklaring voor dit verschil in conditie door het bestuderen van de verschillende factoren die hieraan hebben bijgedragen.

Vorig onderzoek heeft met behulp van SEM-EDX en UHPLC vastgesteld welke materialen en verfstoffen er zijn gebruikt voor de productie van het tapijt. Het grondweefsel bleek van zijde te zijn, de pool van wol en enkele metaaldraden. De gevonden verfstoffen waren indigo of wede, lak, en tannines. Er is een literatuuroverzicht gemaakt om informatie te verzamelen over de oorsprong van het tapijt, de gebruikelijke methodes in onderwaterarcheologie, en hoe deze invloed hebben op de toestand van het object. Op basis van het ontwerp en de kleuren van het tapijt is bepaald dat het in de tweede helt van de 16^{e} of vroeg 17^{e} eeuw gemaakt moet zijn in oost-Perzië.

Een interview met de duiker die het tapijt heeft opgedoken heeft informatie geleverd over de behandeling van het object. Het is mogelijk dat het tapijt stuk getrokken is tijdens het opduiken. Sommige fragmenten zijn gelijk gespoeld en gedroogd, sommige pas de volgende dag, en sommige fragmenten hebben een week lang geweekt. Ze zijn allen gespoeld met kraanwater.

Een conditiebepaling van de fragmenten is opgesteld waarbij werd gelet op de kleur, de hoeveelheid vuil, en de resterende pool. Daarna zijn de factoren die mogelijk hebben bijgedragen aan de conditie van de fragmenten onderzocht. Er kon een direct verband worden gelegd tussen de behandeling tijdens en na het opduiken, en de conditie van elk van de fragmenten. Om deze reden werd dit vastgesteld als de meest belangrijke factor die bijdraagt aan de conditie. De materiaaleigenschappen en de omstanigheden onder water bleken van minder belang te zijn.

Tenslotte werd vraat door bacteriën in zee onderzocht als een mogelijke oorzaak voor de slechte conditie van de wol. Actinobacteriën produceren keratinase: een enzym dat wol vezels aantast. Deze bacteriën worden algeheel in de bovenste laag sediment van de zee aangetroffen. Hoewel er stammen van de *Desulfovibrio* bacterie bestaan die aminozuren kunnen gebruiken, zijn deze sulfaatreducerende bacteriën nog niet ontdekt in de Waddenzee. Het is daarom waarschijnlijker dat fermenterende bacteriën zoals de *Actinobacteria* een bijdrage hebben geleverd aan de slechte conditie van het tapijt.

Trefwoorden: Perzisch tapijt, onderwaterarcheologie, vezelafbraak, conditie beoordeling, spoelen, drogen, sulfaatreducerende bacterien, SEM-EDX

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List of Abbreviations

BZN	Burgzand Noord. One of the sandbanks west of Texel.
EIC	East India Company.
NIOZ	*Koninklijk Nederlands Instituut voor Onderzoek der Zee*. The Netherlands Institute for Sea Research.
RCE	*Rijksdienst voor het Cultureel Erfgoed*. The Cultural Heritage Agency of the Netherlands.
RKD	*Rijksdient Kunsthistorische Documentatie*. The Netherlands Institute for Art History.
SEM-EDX	Scanning electron microscopy - Energy-dispersive X-ray spectroscopy.
UHPLC	Ultra High-performance liquid chromatography.
UvA	University of Amsterdam.
VOC	*Vereenigde Oost-Indische Compagnie*. The Dutch East India Company.

Glossary

cloud-band	Motif derived from Chinese imagery consisting of curling wisps of clouds.
medallion	In carpets: the central image superimposed on the main field. Common shapes are circles, diamonds or quatrefoils.
mordant	A substance added to the dye bath which forms a complex with the dye, attaching it to the fabric. Alum, tannic acids and salts are common mordants.
palmette	Fan-shaped motif named after the resemblance to a palm tree's leaves.
stockinette	A basic knitting stitch where rows of knitting stitches and rows of purls stitches alternate each other, resulting in a very flexible knit.
warp	In weaving: the lengthwise threads held under tension by the loom.
weft	In weaving; the threads inserted over and under the warp, creating a weave.

Introduction

During the summer of 2014 sport divers of *Duikclub Texel* went on multiple expeditions to a shipwreck that rests at Burgzand Noord, a sandbank off the coast of Texel (fig. 1).[1] It is believed the ship sank somewhere in the second quarter of the 17th century. The wreck, labelled BZN17, turned out to contain a great variety of objects ranging from ordinary clay pipe stems, to finely crafted goods. These objects may have been personal possessions of the crew and passengers, but could also have been part of the ship's load.

Among the discoveries were a large number of textile objects, consisting of clothing, accessories, and upholstery fabric. The size and relatively good condition of the find is remarkable, as the conditions underwater are generally not favourable to textiles.[2] Among the many objects was a carpet, which had fallen apart into fragments.[3] It is this curious object that forms the subject of this thesis. Originally presented as consisting of thirteen pieces, a further ten fragments have since then been added to the group. As more objects from the salvage are continuing to turn up, and the group may yet expand further, the focus will be on the original thirteen fragments. As an official name has not yet been given to the object, it will be referred to in this thesis as the BZN17 carpet.

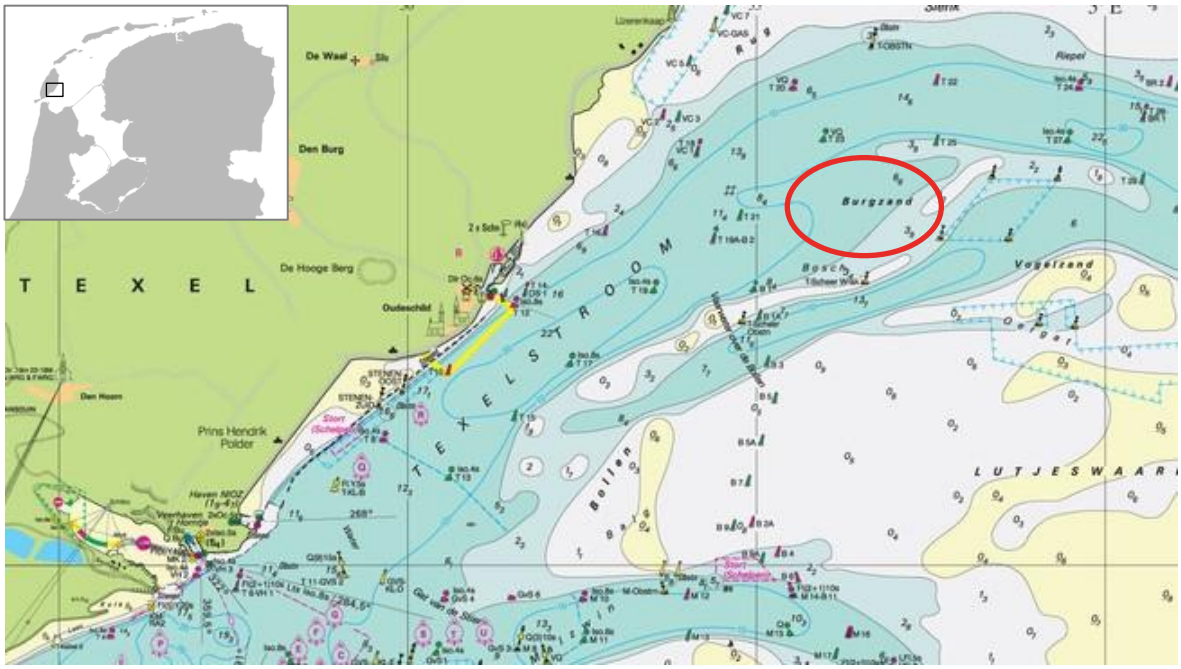


Fig.1 - Detail of a 2013 map of the Waddenzee. Indicated by the red circle (drawn by Lieke Boerstra) is the area of Burgzand Noord where the BZN17 was found.

[1] Braun, T. "Uiterst zeldzame kleding uit Gouden Eeuw gevonden in Waddenzee" *NOS*. 2016. 28 April 2017. <http://nos.nl/artikel/2099146-uiterst-zeldzame-kleding-uit-gouden-eeuw-gevonden-in-waddenzee>.
[2] Florian 2014: 21-23.
[3] Photographs of each of the fragments are collected in *Appendix I*.

The Object

Description

The object consists of thirteen fragments, presumably from the same carpet. Sizes vary between 6x5cm and 30x20cm. It is made of a plain weave ground fabric, through which the pile of the carpet has been knotted. Fragment XIII shows the remnants of a fringe. The object shows various motifs (abstract, floral, animal) in multiple colours (black, red, beige, some blue). This particular decoration pattern shows a strong resemblance to what are known as 'spiral vine carpets with animals', made in Persia during the second half of the 16th century (section 2.2).[4]

The condition of the carpet appears to be very poor. Its fibres are extremely brittle, crumbling under the lightest touch. Fragments show multiple tears and areas of loss. Some of the carpet's pile is retained, but on most of the surface the ground fabric is laid bare. On top of this, the fragments are very dirty; much soil has stuck to the carpet, coating the fragments in a brownish layer. Grains of sand (among other larger particles) are embedded in the weave. Fragment XI consists of two layers which have matted together completely. A more thorough assessment of the condition of the fragments is given in section 4.1.

Provenance

After their salvage one of the divers of Duikclub Texel gathered the fragments and took them to the RKD for examination. Among the experts who had a look at the object were two art historians (Ebeltje Hartkamp-Jonxis and Hillie Smit, who were first to publish an article on the carpet[5]), and a textile conservator specialised in Eastern carpets (Sadegh Memarian). The RKD staff took pictures of the fragments, and created a custom-built box for safe storage. Since then the fragments have been given into custody of the Province of Noord-Holland on behalf of the State, and are kept for research in the UvA Textile Conservation studio at the Ateliergebouw in Amsterdam. From December 2016 through January 2017 the fragments have been exhibited at Museum Kaap Skil in Oudenschild, Texel along some of the other textile objects found in the BZN17.

Aim and Research Question

Although some research has already been conducted on the object, both historical and technical (section 1.2), much remains unknown about the BZN17 carpet, such as its origin or age.[6] The aim of this thesis is therefore to paint a more complete picture by building off the little knowledge already in existence and to gain as much information from the object itself, from similar objects, and from relevant literature.

[4] Klose 2013: 66-75.
[5] Hartkamp-Jonxis & Smit 2016: 36-43.
[6] Hartkamp-Jonxis & Smit 2016, Serrano 2016 and Serrano & Joosten 2016.

The main question raised by the carpet fragments is how their condition can be so poor when compared to the other objects coming from the BZN17, which have presumably endured the same conditions. The cause could lie in the physical properties of the object (its material, manufacture and use during its lifetime), in the conditions it has been exposed to underwater, or in the treatment of the object during and after salvage. The carpet also appears to be the only woollen object retrieved from the BZN17, the other finds consisting primarily of silk. These issues lead to the following main research question:

What are the factors that have contributed to the poor condition of the BZN17 carpet?

Additional questions that will be explored are:

- *What is the current condition of the group of tapestry fragments?*
- *What are the material properties of the carpet and how was it manufactured?*
- *How can underwater conditions contribute to the deterioration of wool and silk?*
- *What has happened to the fragments during and after their salvage with regards to handling and treatment?*
- *How does this carpet compare to objects exposed to similar conditions?*

Relevance for Conservation

The approach of this thesis is diagnostic; the aim is not treat or conserve the object, but rather to analyse it. The results of this analysis may however still contribute to the future treatment of the carpet. If the reason for its poor condition can be determined, further deterioration may be anticipated on.

Any new finds may also benefit from the acquired knowledge. The author is currently unaware of any other cases where an Eastern carpet has been salvaged from a marine environment. Should any be found in the future, this thesis could provide some basic guidelines as to what choices to make with regards to treatment during and after salvage, and how the condition of such an object may be affected by those choices.

Structure and Methodology

To provide a context for this thesis the first chapter will concern itself with the current scientific knowledge. It will address what sort of information is already available from analysis of the fragments and what might be gained from literature on the subjects of Eastern carpets and marine archaeology.

Chapter two will expand further on the subject of Eastern carpets and provides a historic background for the BZN17 carpet. The manufacture, functionality and trade of Eastern carpets, as well as the stylistic groups they may be divided in are briefly discussed. The carpet is then compared to this information; how does the object fit within this historical picture? For this two experts are consulted: Loutje den Tex, textile conservator and art historian, and Sadegh Memarian, textile conservator and specialist in

Eastern carpet manufacturing. Both experts have been invited to study the BZN17 fragments at the UvA Textile Conservation studio.

The third chapter focuses on the treatment the fragments received during and after their salvage up until the point they were given into custody of the Province of Noord-Holland. For this, the main diver involved with the salvage of the object is interviewed and questioned on the exact methods used. This is done in cooperation with Hanneke Kramer, fellow MA Conservation & Restoration student, whose thesis requires the same information.

With knowledge of the historical background, and the treatment of the fragments thus provided, chapter four will delve further into the condition of the BZN17 carpet. A more detailed assessment of its condition is made based on the amount of soiling, its colour, and how much of its pile remains. This condition will be compared to those of two woollen mittens which have also been excavated from a shipwreck in the Waddenzee. These have been sampled by the author and imaged by Ineke Joosten of the RCE using SEM-EDX.[7] A visual comparison will be made between the SEM images of the BZN17 carpet, and the objects mentioned above. Where possible, a connection will be made between the treatment of the fragments and their condition. Several factors that may have contributed to this condition, such as the material properties of wool and silk and their reaction to the marine environment, will be considered.

The fifth chapter will expand on one of potential reasons for the poor condition of the wool pile, which has been brought up by Han Neevel (RCE). He suggested the deterioration could have been caused by the presence of sulphur utilising bacteria in the water and soil. This idea is based on the fact that keratin (wool) contains quite some sulphur, but fibroin (silk) barely does. Answers will be sought in both scientific literature, as well as the expertise at the NIOZ.

The findings of the various chapters will be reiterated in the conclusions. An attempt will be made to answer the research question. A recommendation will also be made for future research on the BZN17 carpet.

[7] These objects, [MA]BZN8220 and [MA]BZN8219, are state property in custody of the RCE and were found in wreck BZN8 nearby BZN17. See also Appendix IV.

1. Current Scientific Knowledge

The aim of this chapter is to explore what has been written so far on the subjects that relate to this thesis. The first section will summarise what has already been written about the BZN17 carpet, and what research has already been done.

Following this, in the second section literature on Eastern carpets will be discussed. Knowledge of these carpets in general provides a context for the BZN17 carpet, and allows it to be seen in a broader cultural and historical perspective. This encompasses both its place of origin in Persia, and its later functional life in Western Europe.

The third section reviews literature on the subject of marine archaeology, with particular attention being given to marine microorganisms. This will help shed light on the conditions that objects are exposed to while underwater, and how it affects them.

Finally, the fourth section discusses how, in light of what has already been written, this thesis fits within current scientific knowledge, how it can expand upon it, and what new insights it may provide. Thus the relevance of this thesis is established.

1.1 Previous Research on the BZN17 carpet

The fragments have been previously written about by two art historians, who published an article on their findings.[8] They give a brief characterisation of the object including its material, manufacture technique and the decorative imagery. Their assumption of the ground weave being made of cotton was later corrected by the research done by Ana Serrano and Ineke Joosten.[9] Additionally, an estimation of the date and place of manufacture is made based on comparisons with similar carpets, placing the object in the second quarter of the 17th century, and originating from about North-Western India. Some further context for the carpet is provided with a description of the trade of Eastern carpets by the VOC. Apart from being the first introduction to the public on the BZN17 carpet, the article lays much of the foundation for further research of the object with regards to its history and material aspects.

The latter have been studied by the UvA and the RCE. In December 2016 SEM-EDX imaging was conducted by Serrano and Joosten.[10] This established the materials used in the carpet (wool, silk and metal thread), identified some of the contaminations present (such as sodium chloride and sulphur-containing products), and provided images of the fibres on a microscopic level. In the same month UHPLC analysis was done by Serrano, to determine which dyestuffs and mordants had been used.[11] Results showed the predominant use of lac-dye, tannins, and indigo or woad in the pile, and no (or no more) dyestuff in the fibres of the ground weave. These two studies provide the basis for the research in this thesis, and their results will be discussed further in later chapters.

[8] Hartkamp-Jonxis & Smit 2016.

[9] The RKD lacks the proper tools and facilities for extensive research, and the authors were limited to gathering information solely from visual observation. Hartkamp-Jonxis & Smit 2016: 37.

[10] Serrano & Joosten 2016, unpublished research.

[11] Serrano 2016, unpublished research.

1.2 Eastern Carpets

Much has been published on the subject of Eastern carpets, with many different approaches and angles. When it comes to placing the BZN17 carpet within a cultural context, two works are of interest. The origins and traditional uses of Persian carpets are discussed in an exhibition catalogue edited by Carol Bier.[12] In her essay on carpets during the late 17th century light is shed on how costly carpets were either exclusively ordered for the court itself, or for its diplomatic relations.[13] This has implications for the original intent of the BZN17 carpet, which may carry values beyond those of a utilitarian object.

In a similar vein, but focused on a slightly earlier period is the catalogue edited by Jon Thompson.[14] According to him the characteristic design of Persian carpets with a central medallion developed under Chinese influence. This influence can also be seen in individual motifs such as rolling cloud-bands and various beasts from Chinese mythology. Thompson rejects the assumption done by earlier scholars, including Bier, that the Persian court had its own carpet workshop. The designs may have been provided by artisans working for the court, but the carpets themselves were produced in independent workshops. He does however agree that carpets of the highest quality (those with a silk ground weave) were made specifically for the court and elite classes. This richness of materials does however have negative consequences for the longevity of the carpets.[15] This information may offer a clue to explain the poor condition of the BZN17 carpet.

The place of the Eastern carpet within Western culture is discussed by Onno Ydema.[16] His book focuses on the depiction of Eastern carpets in Dutch paintings, and emphasises the prestige associated with these particular objects. Ydema makes a direct connection between appearance of Persian carpets in Dutch paintings, and the expansion of the trade relations of the VOC into the Persian Empire.[17] Although this book boasts an expansive catalogue of paintings depicting carpets, there is little attention given to subsets based on style: all Persian carpets are lumped together.

This shortcoming is alleviated by Christine Klose and her article based on the paper she presented in 2007 to the International Council of Oriental Carpets in Istanbul.[18] She identifies a particular type of 16th century carpets hailing from what is now Iran, the 'spiral vine carpets with animals'.[19] Only a few of these carpets survive in museum collections worldwide, making them rare among Persian carpets. Spiral vine carpets are

[12] Bier 1987.
[13] Bier 1987: 98.
[14] Thompson 2003.
[15] "A silk foundation generally indicates either a piece of the highest quality or one that aspires to that status. It also means, unfortunately, that such carpets tend to fall to pieces because the silk becomes brittle with age." Thompson 2003: 290.
[16] Ydema 1991.
[17] Around 1620 Ydema notes a sudden surge in the amount of Persian carpets depicted. Interestingly, these include also carpets that can be dated on stylistic grounds to the 16th century. It seems carpets with outdated motifs were being sold for export. Ydema 1991: 60
[18] Klose 2013.
[19] Klose 2013: 67.

defined both by their particular motifs (animals, flowers, cloud-bands and vines), as well as the use of a silk rather than a wool or cotton ground fabric. Klose suggests that due to their richness, these carpets were likely woven for the Shah.[20] The BZN17 carpet has all the defining characteristics of a 'spiral vine carpet with animals'. This places the object within a very specific and also valuable subset of Eastern carpets. The main value of the article by Klose is the list of spiral vine carpets with animals she compiled.

The catalogue that accompanied the 2007 exhibition of Eastern carpets in the Museu Nacional de Arte Antiga in Lisbon combines both the Oriental and the Occidental contexts, and ads to this modern scientific research.[21] Due to its nature of being an exhibition catalogue, the information given is pretty general and somewhat superficial. A notable exception is the chapter by Heitor et al: an analysis of the dyestuffs using HPLC was done on nine of the Persian carpets in the exhibition. Whereas the results for the red and the blue dyes are similar for all carpets, the dyestuffs used for the yellow areas show much regional variety. This allows this colour to be used as way of establishing the origin of the carpet.[22] Another example of Portuguese research on Persian carpets is the work of Armindo et al.[23] The article discusses the outcome of material, technical and art historical study on a 16th century carpet, as well as the conservation of the object. The structure and methodology of this study form a valuable example for this thesis.[24]

1.3 Marine Archaeology

Marine archaeology is a very broad, and much written about topic. Textile finds make up a small percentage of marine archaeological finds, but are nonetheless well represented in literature. A clear development can be seen in the shift of focus from treatment, in particular cleaning, of the object to analysis and minimal intervention. An early example is the work of Kenneth Morris and Betty Seifert.[25] This describes the (in modern eyes) rather rigorous treatment of a linen object. Although seemingly a successful result was achieved, the authors emphasise the experimental nature of their method.[26] This article illustrates how conservation treatments in marine archaeology are subject to on-going development, with standardisation of practice still in progress. This is further reflected in

[20] Klose 2013: 75.

[21] Pereira, Teresa and Jessica Hallett, eds. *The Oriental carpet in Portugal: Carpets and paintings, 15th-18th centuries*. Lisbon: Ministerio da Cultura, 2007

[22] For the yellows a wide variety of berries, flowers, roots and stems had been employed to achieve their colour, all plants grown in particular regions. Heitor et al. 2007: 164.

[23] Armindo et al. 2008.

[24] Analytical techniques used on the Portuguese carpet include optical microscopy, SEM and HPLC to determine both the materials as well as the dyestuffs used. The results were used to determine the appropriated conservation treatment of the object.

[25] Morris & Seifert 1978.

[26] "The use of modified immersion solutions, oxalic acid to reduce metallic encrustations and freeze-drying for textiles are not necessarily solutions for the problems of other underwater sites, as each site varies due to biological and other environmental conditions. Other treatments and procedures related to leather and textiles are still under investigation." Morris & Seifert 1978: 40.

a later article by Kathryn Jakes and John Mitchell.[27] After a short summary of methods used by their predecessors, both successful and unsuccessful, Jakes and Mitchell compare five different methods for drying textiles from wet archaeological sites. Focus is put on mechanical damage occurring during the drying process measured from images of the fibres obtained with SEM-EDX. They concluded slow drying in a freezer is the best methods for textile objects, although some damage is inevitable.[28] Apart from the drying, the rinsing of archaeological objects may also have a damaging effect, as discussed by Maj Ringaard.[29] Using SEM-EDX imaging wool fibres show a much higher degree of deterioration after rinsing with a soft water jet, as opposed to those that weren't rinsed.[30] The information of both articles is relevant for the BZN17 carpet when considering the factors contributing to its current condition. The most up-to-date views are presented by Colin Pearson.[31] Particularly interesting is the chapter by Victoria Jenssen who, apart from discussing treatment of marine artefacts, also gives several options for storage and display.[32] These may be of interest for devising a better storage method for the BZN17 carpet. Pearson's guide reflects the latest ideas and procedures in marine archaeology; the benchmark against which the salvage of the BZN17 can be compared.

For archaeology specific to the situation of Burgzand, the area of the Waddenzee where the BZN17 was found, the work of Arent Vos is indispensable.[33] It provides the historical background of the area, insight into how shipwrecks are covered and uncovered by the shifting sands, and how a professional salvage operation is conducted. Additionally the book includes an inventory of all the shipwrecks and the artefacts they contained found at Burgzand prior to 2012. Even though this does not describe the BZN17, which was salvaged several years later, it shows the type of objects which survived in other ships under similar conditions. The wreck of BZN8 is especially useful, as here several woollen objects were uncovered which remained in surprisingly good condition, making them an interesting case study for comparison.[34]

Not much has been written on the subject of the deterioration of textile in the underwater environment. This was noted by Elizabeth Peacock, whose review of literature published on this subject forms a valuable overview.[35] In addition to what is known, her article also highlights those areas where comparatively little research has

[27] Jakes & Mitchell 1992.

[28] "An examination of different methods of drying linen trunk lining textiles suggested that slow drying of frozen textiles appeared to be a less disruptive method of drying and preservation than vacuum freeze drying. Vacuum freeze drying was more disruptive in its effects than air drying, ethanol dehydration, critical-point drying, or slow drying in the frozen state." Jakes & Mitchell 1992: 352.

[29] Ringgaard 2011.

[30] "In general textiles subjected to aqueous rinsing were in a poorer condition than textiles that had only been freeze-dried. SEM micrographs showed missing scales and many holes in the fibre surface although the scales are still visible in the areas between the eroded parts […]" Ringgaard 2011: 4-5.

[31] Pearson 2014.

[32] Jenssen 2014.

[33] Vos 2012.

[34] Vos 2012: 212.

[35] Peacock 1996.

been done; she found the study of microbial deterioration of fibres to be especially lacking.[36] One notable exception is the research conducted by Susumu Takii.[37] His study found amino acids to be the main source of nutrition for sulphate-reducing bacteria living in marine sediment. Although no direct comparison can be made to sulphate-reducing bacteria living in the Waddenzee, it may provide a basis for the hypothesis that the deterioration of the wool from the BZN17 is due to microbial attack.

1.4 The Position of This Thesis within Current Scientific Knowledge

The aim of this thesis is to expand upon the knowledge that has already been gained by previous research on the BZN17 carpet. The article by Hartkamp-Jonxis & Smit provides the starting point for deeper research into the history of the object, and its cultural context. The material knowledge gained from the UHPLC and SEM analysis done by Serrano and Joosten forms a solid base for assessing the condition of the carpet.

The subject of the Eastern carpet has been widely researched and has a great deal of literature dedicated to its topic. Thorough study has been done on the cultural context of carpets, their manufacture, the different stylistic types (including the specific subgroup of 'spiral vine carpets with animals' that the BZN17 carpet appears to belong to) and their material characteristics. It can therefore not be expected that this thesis will add much to this already existing knowledge. Instead it will mostly draw information from this literature, which will provide a historic context to the BZN17. Additionally, it may also serve to connect already existing knowledge in new and meaningful ways.

In contrast, much new knowledge can be gained in the field of marine archaeology. The scarcity of marine textile finds means that each newly found object provides valuable insight. Of particular importance will be the comparison of the BZN17 carpet to the woollen objects found in the BZN8. These are in a very different condition even though they have been salvaged from the same area of the Waddenzee. Understanding the factors contributing to this difference in condition will expand the knowledge on the degradation of proteins in the underwater environment. In turn, this knowledge may be used to better understand and preserve any future textiles that are salvaged from the sea.

[36] Peacock 1996: 37-38.
[37] Takii 2003.

2. Eastern Carpets

The terms 'Eastern carpet' or 'Oriental carpet' cover a rather broad geographical area in view of the objects they describe. Ranging from the nearby Byzantine Empire to as far as China and India the terms are applied to any carpet produced outside of the early modern western world. To complicate things further, each scholar uses their own definitions and classification.[38] [39] Although attempts have been made to design a unified system for the classification of carpets, either based on technique or stylistic characteristics, today no single system is universally accepted. Indeed, opposition against a taxonomic model is voiced by those pointing at the fact that there is no singular evolutionary development: over time different styles were used and re-used with sometimes much older carpets serving as the model for brand new ones.[40] Using the term 'Persian carpet' is no less problematic. The Persian Empire existed from the first dynasty in 550 BC, all the way up to the Iranian Revolution in 1979 when the last Shah was overthrown, and at one point spanned from the Balkan to the Indus valley.

To narrow down the scope a little, the focus of this chapter will be on the era in Persian history during which the BZN17 carpet was presumably created, the Safavid dynasty (1501-1736).[41] All of the other carpets discussed in this thesis are also from this period. First, attention will be given to the manufacturing process of carpets, and how they functioned in daily life, both in Persia and in Europe. Then, the various styles and designs of Persian carpets that have been manufactured during the Safavid dynasty will be discussed. Finally, the characteristics of the BZN17 carpet are examined, and an attempt is made to place the object within the historical framework.

2.1 Manufacture and Functionality

During the Safavid era the court was supplied by both royal workshops and workshops of the free market which had their artisans organised into guilds. Carpet workshops under direct patronage of the court generally produced the highest quality goods. These have been evident from the earliest years of the dynasty, and continued their existence until its very end.[42] Under the rule of Abbas I (reigning from 1586-1628) a more commercial interest began to develop. The royal workshops started not only to provide in the need for goods for the court itself, but also to produce merchandise to be sold for profit on foreign markets, including India and Europe. As demand grew more private workshop were established.[43]

[38] One example is the work of May Beattie, who grouped together carpets based on the colour, style, and patterns of the main field. Beattie 1976.
[39] A system of classification based on the patterns used in the borders has been designed by Onno Ydema. Not surprisingly, this classification yields different results than that of Beattie, Ydema 1991: 61-63.
[40] Thompson 2003: 298.
[41] A detailed narrative on the Safavid dynasty and its dealings with Europe can be found in Appendix V.
[42] Thompson 2003: 273, 280.
[43] Savory 1986: 354-55.

Materials

A variety of materials may have been used to manufacture carpets depending on the place of origin and the costliness of the piece. Silk and metal threads were the most expensive options, with cotton and wool being used as cheaper alternatives.[44] The main production of silk took place in the provinces of Georgia, Shirvan and Gilan, which had the right climate for growing mulberry trees (*Morus alba L.*) and rearing the worms of the silk moth (*Bombyx mori L.*). The silkworm is fed on mulberry leaves until it reaches the pupal stage and starts spinning its cocoon. This cocoon is made of a single silk thread which can reach lengths of over 900 m.[45]

The finest quality wool came from goats farmed in Kirman, from which the wool also gained its name.[46] Sheep's wool was also used as it was less expensive, the quality of the fibre depending on the breed of the animal, and the part of the body it grew on. The hairs are washed, carded, and spun into a thread. The great benefit of wool over silk is that it takes to dyes much better, making it easier to create darker colours.

For dying fibres a variety of natural dyes were used, both from domestic and foreign sources. Mordants such as alum were used to attach the dye to the fibres, and improve the light fastness of the colour.[47] Madder was produced in Persia, but cochineal, lac and indigo were imported from India.[48] While madder and indigo were widely used, the yellow dyestuffs often came from a much more local source. This colour could therefore serve as an indicator of the origin of the carpet.[49]

Technique

Carpets are created on a loom which holds the warp threads under tension. The weft thread is inserted through the warp. It is often made of the same material (usually cotton or wool). Then a single row of knots is made over the warp threads, with the ends cut off and projecting towards the weaver. Another weft thread is inserted and beaten down to secure the knots. This creates a slight slope to the knots, giving the pile a downward angle. After the carpet is finished it is shorn to create a pile of even length. The excess warp threads are knotted together and used as a fringe. The number of warp threads the knot is made over, and the shape and direction of the knot may vary depending on regional practice. The type of knot dictates their density, which in turn has an effect on the fineness of the design that may be achieved. In Persia the most common knot was an asymmetrical one over two warps threads (also known as the *Senneh* or *Senna* knot), although other variants were also used (fig. 2).[50]

[44] Hallett 2007a: 26.
[45] Ferrier 1986: 441.
[46] Other animals whose wool may be used were Cashmere goats, and camels. Ferrier 1986: 480.
[47] Hallett 2007a: 24-25
[48] Ferrier 1986: 448.
[49] Due to its faster rate of fading yellow areas in carpets tend to have changed colour much more than other areas. This makes it difficult to interpret their original colour. Heitor et al. 2007: 162.
[50] Hallett 2007a: 26.

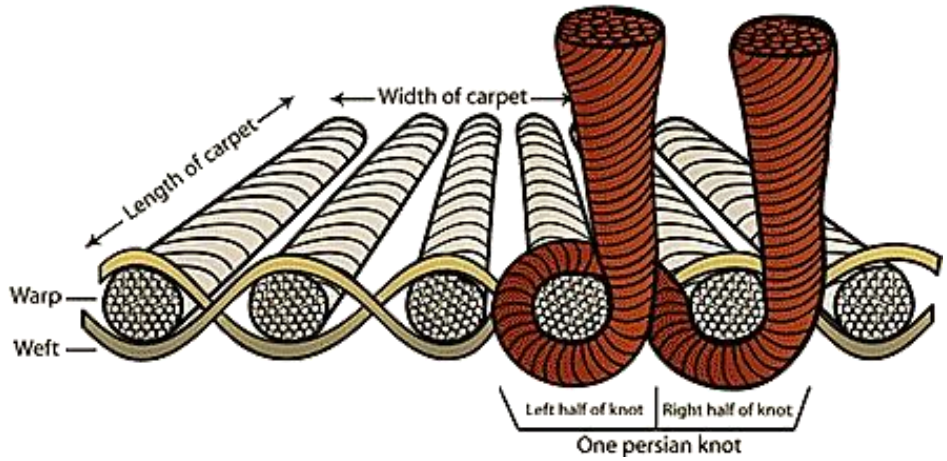


Fig. 2 - schematic drawing of a Persian or Senneh knot. The left warp thread is covered by the knot, the right warp thread is not. (Source: <http://www.arearugfacts.com/hand_knotted_rugs.php> 19 May 2017.)

The design of a carpet is achieved by alternating the colours of the woollen or silk knots of the pile. The pattern may be recreated through the memory of the weaver, but can also be copied from a cartoon, written or sung instructions, or by copying another carpet.[51] Older objects were used as models, but were often copied with a lesser degree of finesse, and in less costly materials. Due to this motifs became less detailed and more angular and simplified over time. This was a direct result of the growing demand for large-scale production and the commercial interests involved with carpets.[52] Although the technique of carpet knotting is fairly simple, faithfully reproducing a pattern from a drawing required a high degree of skill.[53]

Functionality

Within Persia carpets were multifunctional objects which covered not only floors, but also doors, windows and walls. In a sense they were portable pieces of architecture, used to create a space rather than decorate it. This is especially apparent in the case of prayer rugs, which carry within them the ritual functions of a mosque.[54] The designs of a carpet may hold a clue as to its intended use. Carpets with a single pictorial design had one way of being viewed correctly, and would have hung vertically. In contrast, carpets with a central design with both horizontal and vertical symmetry could be viewed from all directions, and were more likely to have been used as floor coverings.

In the Netherlands, and the rest of northern Europe, it was not until well into the 18th century that Eastern carpets were used on the floor. Although they would occasionally appear as such on paintings, their rarity and costliness would warrant a more careful treatment. Carpets would generally be used to cover furniture such as tables and

[51] Bier 1987: 101.
[52] Roemer 1986: 275-76.
[53] In fact, carpet weavers working for the court were paid an equal amount as the royal silk weavers. Thompson 2003: 288.
[54] Prayer rugs are used to create a sacred space in the absence of an actual mosque, and include a niche at the top which is pointed towards Mecca during prayer. Hallett 2007b: 23.

trunks.[55] From the moment that the EIC and the VOC established trade relations with Persia, carpets were only rarely among the exported goods. Both parties considered them too expensive to be used commercially, and the few that were exported were either private purchases, or meant as gifts for the elite in Europe or Asia.[56] Silk carpets with details in metal thread were especially suited as diplomatic gifts as they were considered the most prestigious.[57] Eastern carpets were exotic novelties, and as such they were often depicted in portrait painting as tokens of wealth and worldliness (fig. 3). From 1624 onward Persian carpets appear in great numbers in Dutch paintings, and their popularity peaks around 1660-1680. At that time there appears to have been a point of saturation, and the number of depicted carpets dwindles.[58]

2.2 Stylistic Groups

No Persian carpets from before the Safavid period have survived, but depictions of them can be seen in the miniatures of the 15th century. Some of these show carpets with a central medallion and a ground with swirls and animal figures, indicating that the carpets of the Safavid period were a continuation of this earlier style (fig. 4).[59] Vice versa, designs made for illumination painters were used by carpet weavers as a source of inspiration, creating ever more intricate variations.[60]

The dating of carpets is problematic as no records kept by the carpet workshops have survived, and the carpets themselves were generally not provided with a date.[61] Apart from dating, assigning the place of origin to a carpet is also difficult. It can be assumed that the royal carpet workshop travelled along with the court when it moved to a new capital. This means workshops presumably existed in Tabriz, in Qazvin from 1548 onwards, and in Isfahan from 1598. Of the latter it is known that carpets brocaded with gold and silver were manufactured there.[62] The large silken carpets that were ordered by King Sigismund III of Poland in 1601 from Kashan indicate that the industry of weaving silk carpets was also well established there at that period in time.[63] In general, the more complex the design of the carpet, the more likely it was made under court patronage.

[55] Ydema 1991: 7.
[56] Bier 1987 :23.
[57] This type of carpet was gifted by the Persian envoy during his visit to the Netherlands in 1625 after the establishment of trade relations between both countries. In turn, the Dutch purchased several of these carpets as gifts for diplomatic missions to the Far East. Ydema 1991: 67.
[58] Contemporary sources mention a growing distaste for Persian carpets, which would yield only one-third of their original price on the Dutch market. Ydema 1991: 59-61.
[59] Spuhler 1973: 699.
[60] Hallett 2007b: 79.
[61] Only four carpets exist with the date of manufacture woven in them, the earliest dating 1522-3, and the latest 1671. Although some general observations about their stylistic characteristics can be made, the sample of four is too small to provide any sort of basis for reliable dating. Spuhler 1973: 700-01.
[62] Contemporary sources generally mention only carpets made with a silk pile, as woollen ones were considered not as impressive. One notable exception is a description from 1684 by Engelbert Kaempfer of a banqueting hall in Isfahan: "[…] woollen rugs from Kirman with animal patterns and woven from the finest of wool." Spuhler 1973: 702-03.
[63] Ydema 1991: 69.



Fig. 3 - A portrait of Cornelis Jansz Meyer, a hydraulic engineer, posing next to tokens of wealth and knowledge such as the globe, the book with construction drawings and of course a large Persian carpet. Abraham van den Hecken, 1650-1655.

Simple designs of repeating units were more easily produced and required less skill than pictorial carpets where the whole field is filled with a single, non-repeating design.[64]
There are some definitive principles to which the designs of Persian carpets adhere: a rectangular inner field, enclosed with a border consisting of multiple bands. The centre field has a multi-layered composition of repeating patterns. On this basis several variations were made. The most common design is symmetrical in both directions, and features a central medallion. In 16th century carpets this medallion has a clearly defined contour, in 17th century examples the distinction between medallion and ground becomes gradually blurred. The ground itself is filled with two layers of superimposed motifs, such as vines overlapped by animals or figures. Many of these were derived from Chinese examples, such as dragons, phoenixes, guardian lions and cloud-bands (fig. 5).[65] There are several theories about the meanings of these animals, from the lion devouring an animal being a representation imperial power, to the animals as a group symbolising the Safavid cosmology.[66] The name for this common type of carpet varies by author and may be referred to as 'star medallion carpet' (Bier 1987), 'Indo-Persian carpets' (Ydema 1991), or 'cartouche carpet' (Hallett 2007).



Fig. 4 - Detail from a book illumination showing two men sitting on a Persian carpet. Shaikh Zada, ca. 1525-35.

[64] Bier 1987: 104-05.
[65] These elements were already common motifs in book illumination from before the Safavid period. Spuhler 1973: 704-07.
[66] Bier 1987: 213.



Fig. 5 - Two details from a Persian carpet showing a dragon (left) and a phoenix and cloud-bands (right).

One stylistic subtype of these carpets is the 'Herat carpet', defined by large palmettes and very narrow scrolling vines, named after the city in the north-east of Persia. Early examples from the 16th century feature cloud-bands and have details accentuated with metal threads. Many incorporate mythical creatures, and animals preying on each other. Examples from the 17th century show a more simplified floral pattern and no animals. This is the type that was most popular in Holland and Portugal, and is the most commonly depicted in Dutch painting.[67]

2.3 The BZN17 Carpet

Physical characteristics

On 19 May 2017 the fragments of the BZN17 carpet have been studied by textile conservator and specialist in Eastern carpets, Sadegh Memarian.[68] With the aid of a Carl Zeiss OPMI 9-FC microscope the weaving structure and knot density were examined. The following things could be established with certainty: the carpet was created using Persian knots (or *Senneh* knots) (fig. 2). Between each row of knots there are three rows of weft threads, woven in plain weave (Appendix III, fig. III.4 and III.5). The density of knots was counted at 9 by 9 knots per cm^2, and 18 by 18 knots per 4 cm^2, giving an estimated knot density of around 8.000 knots per dm^2. Additionally, Mr Memarian was able to estimate, based on the size of the motifs, that the original size of the carpet was around 240-250 cm in length, and 170-180 cm in width.

Stylistic Characteristics

On 30 May 2017 the fragments were studied by a second textile conservator, Loutje den Tex, who specialises in the historical aspect of Eastern carpets.[69] Together with the author the main stylistic characteristics of the BZN17 carpet were established:

[67] Spuhler 1973: 710-11.
[68] Memarian 2017, unpublished interview.
[69] Tex 2017, unpublished interview.

- Dark red, almost purple main field.
  Persian carpets tend to incorporate more bright reds, whereas purple reds are more often found in Indian carpets.
- Pale coloured spiral vines in the main field.
  A typical element of the 16th century 'Herat carpets'.
- Black outlines for all figures, except the cloud-bands on the main border.
  Many Persian carpets show outline in multiple colours, ranging from black to white and red, depending on the neighbouring colours.
- Pale coloured main border filled with cartouches, framed by pale coloured outer and inner borders.
  The combination of a main field with animals and a border with cartouches is unusual. More often carpets with animals had large floral borders (fig. 2 and 5).

An interpretation of what the design of the border may have looked like was also made together with Ms den Tex. Photos of several fragments were merged together to create a reconstruction. An image of this can be found in Appendix V.

Historical Context

Combining the above expertise with the knowledge gained from literature allows for the construction of a well-founded historical context for the BZN17 carpet. Previous research has established that the dyestuffs used in the object are tannins, lac-dye, and indigo or woad.[70] The latter two are commonly seen in many Persian carpets.[71] This reinforces the idea that we are dealing with a Persian object rather than a carpet produced elsewhere.

Looking at its stylistic characteristics, the BZN17 carpet has several features in common with Safavid carpets of the 16th century: the presence of a central medallion with a well-defined outline, and a central field filled with narrow scrolling vines and animal figurines. Had the carpet been made in the 17th century one would expect the medallion to be less defined, and an absence of figurines. Furthermore, we can also see the various large palmettes and accents made of metal thread which are typical for the so called 'Herat' carpets. Based on appearance alone, it is reasonable to assume the origin of the BZN17 carpet to be the city of Herat, in what is now Afghanistan. If this is the case, it is unlikely the carpet has been made in a royally commissioned workshop, as Herat was never the capital of the Persian Empire. This does not necessarily mean that the design is not modelled after or copied from a royal carpet.

Some characteristics of the carpet however are unusual for 'Herat' carpets, such as the dark red main field which is a colour more often associated with Indian carpets. Another deviant element is the presence of cartouches in the main border. When looking at other carpets labelled as belonging to the 'Herat' type, a border with large flowers or

[70] Serrano 2016, unpublished research.
[71] By analysing 153 samples from nine different carpets it was found that for each object the reds and blues derived from the same dyestuff, and only the yellow varied. Heitor et al. 2007: 165-67.

palmettes is much more common. For instance, of the nine 'spiral vine carpets with animals' described by Klose, none has a main border filled with cartouches.[72] A carpet with very similar characteristics is found in the collection of the New York Metropolitan Museum (fig. 6). According to its description it was manufactured late 16th century in Iran, and is made of a silk ground weave and an asymmetrically knotted woollen pile. Like the BZN17 carpet it has the dark red main field, border with cartouches, and the figures outlined in black. There are also certain differences (such as filling of the main field with both spiral vines and cloud-bands) which make it uncertain whether the BN17 carpet can really be attributed of having the same provenance.

The use of wool for the pile is an indication that although this was an expensive object, it was not created for the absolute elite (i.e. the Safavid court), who may have preferred a carpet fully made of silk. However, having a silk ground weave, and the inclusion of silver and possibly gold metal threads suggests the BZN17 carpet was still a luxury object. This is attested by the high knot density of the object as a higher knot count not only lends itself for a more refined design, but also increases the necessary skill, and therefor price of the carpet.



Fig. 6 - Detail of the Metropolitan carpet showing characteristics similar to that of the BZN17 carpet.

[72] Klose 2013.

The BZN17 carpet in an earlier publication

It is interesting to note that the previous study on this carpet, the article written by Hartkamp-Jonxis and Smit, has drawn some different conclusions regarding its age and origin.[73] Rather than a 16th century Persian carpet, the BZN17 carpet is presumed to be made in North-Western India, during the second quarter of the 17th century. This is based on its similarities to another carpet from that region, the Fremlin carpet of the Victoria & Albert Museum (fig. 7), and the fact that a Jacob's staff carved with the year "1636" was also found in the BZN17 shipwreck.[74] Both arguments can be refuted, for different reasons. The presence of the Jacob's staff only indicates the cut-off point for the sinking of the ship, which could not have taken place before 1636. It does not however hold any relation to the age of the carpet which could have already been several decades old at that time. When it comes to the resemblance to the Fremlin carpet, although there are some obvious similarities, there are also several clear distinct characteristics. The defining features of the 'Herat' carpet, the narrow scrolling vines which fill the background of the main field, are not present on the Fremlin carpet at all. Instead, a variation of trees, plants, and branches are used to fill any voids. Their rendition, and that of the many animals, is much more angular and coarse compared to the smooth flowing line of the BZN17 carpet. Although both carpets draw from the same set of motifs, their execution is very different indeed.



Fig. 7 - Detail of the main field of the Fremlin carpet.

[73] Hartkamp-Jonxis & Smit 2016.

[74] "Het toeval wil dat het tapijt waarvan de fragmenten in het scheepswrak op de Rede van Texel zijn aangetroffen [...] hoogstwaarschijnlijk eveneens uit het tweede kwart van de zeventiende eeuw stamt. Hiervoor zijn twee redenen: de overeenkomsten met het Fremlin tapijt en het jaartal 1636 dat is ingekerfd in een houten Jacobsstaf, die eveneens in het wrak is aangetroffen." Hartkamp-Jonxis & Smit 2017: 40.

3. Treatment of BZN17 carpet

To understand its current condition, it is vital to know what has happened to the BZN17 carpet in terms of treatment from the moment it was found up to the point where it was handed into custody of the State. This information was provided by the discoverer of the carpet during an interview which was held on May 16 2017, together with fellow student Hanneke Kramer. Due to the sensitive nature of the proceedings around the salvage of the BZN17 this interview was conducted anonymously, and will not be published in this thesis. Instead, the following three paragraphs will be a paraphrase of the interview's outcome.

3.1 Salvage

The wreck of the BZN17 had been first discovered by members of *Duikclub Texel* in 2009, and from 2010 on the discoverer of the carpet (from now on referred to as 'the Diver') undertook occasional expeditions to the site to observe how much of it had been uncovered from the sands. It was not until 2011 that it became apparent that the BZN17 was a complete ship rather than just some wreckage when both sides of the frame and a canon had become visible. It was at this point that the members of *Duikclub Texel* signed an agreement among each other that any finds would be given to the Kaap Skil museum. By 2013 much of the stern and some of the middle of the ship had been revealed, and the number of finds increased. From the location of the finds their function was determined: objects found in the stern of the ship had been part of the personal possessions of the officers, whereas objects pulled from the middle had belonged to the ship's cargo.

It was in this middle area that in the summer of 2014 the Diver discovered the BZN17 carpet. The exact date is unknown, but it was three weeks prior to the finding of most of the other textile objects, also from the middle of the ship. That day the weather was fair, but underwater visibility was poor. This meant that the search for objects depended on touch rather than sight. At one point the Diver felt something soft, which he was able to grab and pull away. Two or three grabs were done and the clumps of material were placed in the net carried by the Diver. It was only when this net was brought up and emptied that the Diver and the other crewmembers realised they were dealing with textile. The objects were covered in filth ('snot'), black and pungent, and were not treated until the expedition returned ashore. The Diver conceded that it might be possible that he had pulled apart the carpet during the salvage. He supposed that more of the object could have been preserved if the underwater visibility had been better and it had been discovered earlier that he was dealing with a piece of textile.

3.2 Cleaning and Drying

After their salvage the carpet fragments were brought to the diving club's clubhouse in Oudeschild, Texel. Two of the fragments (I and II, see Appendix I) were rinsed there. This was done in a bucket of cold tap water without any additives. The water was repeatedly refreshed until the fragments stopped giving off dirt. Afterwards the two pieces were laid

to dry in the sun on some timber outside of the building. This took no longer than an hour. Fragment I was kept by the Diver, fragment II was taken by one of his fellow club members. The remaining pieces were left untreated and wet. They were packed in a plastic bag and brought home by the Diver.

Here the fragments were rinsed in cold tap water inside the bathtub. Again, no additives were used and the water was refreshed several times. During this stage the Diver pulled several of the pieces apart that had matted together. As they were wet and soft, this took little force. He only left one piece as it was (fragment XI), as evidence of how all of the fragments had once been stuck together. This piece was also rinsed less thoroughly, and retains most of the dirt. The drying was done in the attic, which is an insulated space without any direct sunlight. As it was summer temperatures are estimated to have been between 20 and 25 °C. The fragments were placed on filtration paper on top of a thick layer of newspapers, and left for up to three weeks.

It was later discovered that two pieces (fragment XII and XIII) had been left behind at the clubhouse, soaking in a bucket of tap water for roughly a week. They were dried at the clubhouse, and later taken by the Diver, along with fragment II, to be put with the other carpet fragments. All thirteen pieces were now with the Diver.

3.3 Storage and Handling

After the fragments had fully dried they were gathered by the Diver and put in cardboard folders, two to four at a time. Sheets of filtration paper were used to cover both sides of the fragments, preventing them from touching each other and the folder itself. Fragments I and II were put in a photo frame with a sheet of filtration paper as a backing. These two frames were then taken to the workplace of the Diver, where they were first seen by Laurens Schoemaker, a specialist in maritime painting at the RKD. It was Mr Schoemaker who recommended the find to be looked at by Mrs Hartkamp-Jonxis and Mrs Smit. They also viewed the two fragments at the workplace of the Diver, and requested to see all the pieces. The Diver then took home fragments I and II, removed them from their frames and packed them in the same manner as the other pieces; in filtration paper and folders.

Mr Schoemaker picked up all the pieces and took them to the RKD in The Hague for research and photography. An agreement was made between the Diver and Mrs Hartkamp-Jonxis that she would study the objects and write a publication on them, but that no samples were to be taken. It was at the RKD that the fragments were given the custom-built storage box of acid-free cardboard and foam in which they are still kept today. In the autumn of 2015 the objects were returned to the Diver. The fragments left the care of the Diver in early 2016, when the box was brought to Texel. There they first stayed at Museum Kaap Skil and then at the diving club for a brief time, after which they were handed into the custody of the province of Noord-Holland on behalf of the State, and kept at the Ateliergebouw in Amsterdam.

4. Condition of BZN17 fragments

In the previous chapters the possible origin of the carpet, and the treatment it received during and after its salvage have been discussed. This chapter will focus on the condition of the object as a whole, and its individual fragments. An attempt will be made to establish which factors have contributed, whether positively or negatively, to the current condition of the carpet.

First, an assessment of the condition of the fragments will be made based on three different parameters. Next the condition will be compared to that of other objects which have been exposed to a similar underwater environment. Does the BZN17 carpet show any marked differences, or do these objects found in the Waddenzee share the same general condition? The next paragraphs will each focus on a different factor: one on the characteristics of the materials of which the carpet is made, the other on the various treatments the fragments have undergone.

Hopefully knowing how these various factors can contribute to the condition of the object not only furthers our understanding of the carpet and its current state, but may also help in the decision of how to deal with objects like this in the future.

4.1 Condition Assessment

Assessing the condition of an object is not an exact science. Although some aspects may be objectively quantified with the aid of specialist equipment, such as measuring the tensile strength of fibres, condition assessments tend to also incorporate subjective elements. This is also the case for the BZN17 carpet where the assessment was based on its colour, the amount of contamination or soiling, and the amount of remaining pile. This was done by the author solely through visual observation and without the help of any tools. A detailed condition description of each fragment can be found in Appendix II.

A simplified overview is given in the table below (table 1). The ‘Colour’ parameter refers to the intensity of the colours and is based on a relative scale ranging from the fragment with the least intense colours to the fragment with the most intense colours. The ‘Contamination’ parameter refers to the amount of contamination visible on a fragment, whether sand, soiling, or otherwise, with the fragments showing the least contamination scoring the highest. The ‘Pile’ parameter refers to the amount of pile remaining on a fragment. In the case of colour and contamination both sides of the fragments were assessed, and the final score reflects the average condition (i.e. if both sides showed intense colour the average score is ‘++’, but if on one side the colours had faded the average score is lowered to ‘+’).

Looking at the results of the condition assessment there seems to be some relation between two parameters: fragments which had less faded colours also retained more of their pile. But where one might expect fragments that have been rigorously cleaned to have less pile remaining, the results in table 1 show otherwise. This may partly be due to the subjective nature of the observed parameters. Unfortunately a more objective assessment could at the time not be performed.

Fragment	Colour	Contamination	Pile
I	+	++	++
II	+/-	++	+/-
III	+/-	+	++
IV	+/-	++	+/-
V	-	++	+/-
VI	-	-	+/-
VII	+	+/-	++
VIII	+/-	++	+/-
IX	-	-	++
X	+/-	++	+/-
XI	++	--	++
XII	--	-	--
XIII	--	++	--

Legend:
++ = good condition
+ = fair to good condition
+/- = fair condition
- = poor to fair condition
-- = poor condition

Table 1 - summary of the condition assessment of the BZN17 carpet fragments.

Some general observations about the condition of the fragments:

- In fragments where both the red and the black pile remains, the black pile is longer, cleaner, and less matted than the red pile (Appendix III, fig. III.1-3).
- When looking at the different types of fibres within a fragment, the wool shows a higher degree of contamination than the silk (Appendix III, fig. III.5).
- The areas that are blue coloured (such as the bottom right corner of fragment X, or the bird's head of fragment VII) would have originally been filled with metallic threads. Remnants of the metal layer which have now turned black can still be observed (Appendix III, fig. III.6). SEM analysis on one of these areas found the presence of silver sulphide, the corrosion product of silver.[75] The presence of silver sulphide supports the hypothesis that part of the deterioration was caused by sulphur utilising bacteria, which will be discussed in chapter 5.
- The two fragments which were soaked in water for a week, XII and XIII, show by far the greatest loss in both colour intensity and pile. The fragment which was rinsed the least, XI, shows the greatest intensity of colour.
- Fragment II and X were originally a single piece (fig. 8). This became evident when a photograph taken by one of the members of *Duikclub Texel* turned up during research done by Hanneke Kramer. The picture showed a single piece of carpet, which was drying after being rinsed at the clubhouse, showing both the leaping deer and the head of the dragon-like creature. The damage which caused the piece to tear into two pieces must have taken place between the moment the photograph was taken and the point where the custom storage box was created at the RKD.

[75] Serrano & Joosten 2016, unpublished research.



Fig. 8 - Fragment II and X pieced back together.

4.2 Condition of Comparable Objects

Some 300 metres from the BZN17 lies another shipwreck, the BZN8, which sank in the third quarter of the 17th century. Several textile objects were found during diving expeditions by the RCE, including two woollen objects: a complete mitten, and the lining of a leather mitten (fig. 9). Both mitten and lining are made of plain wool knitted with a stockinette stitch. As the objects have been exposed to similar conditions for an equal amount of time, a comparison to the BZN17 carpet in terms of condition is interesting. This may provide insight in how big a role environmental factors play. More information about the objects may be found in Appendix IV.

At first glance the lining appears to be in a worse condition than the mitten: the lining is distorted and torn. Its surface is very matted, obscuring the texture of the knit. There is also more soiling in the form of grains of sand and a grey mud-like layer. Samples were taken by the author to be used for SEM imaging, performed by Ineke Joosten of the RCE. The images of samples L.1 and L.2, from the lining, showed great amounts of contamination. Among the mud, sand grains, pyrite and diatoms (unicellular phytoplankton) it was difficult to find the wool fibres (Appendix IV, fig. IV.1-4). However, the fibres themselves were in a really good condition: the scales were still clearly visible, with well-defined edges (Appendix IV, fig. IV.6). The main type of damage to the fibres appeared to be of a mechanical nature: fibres were snapped or pulled apart, the fibrils of the core broken (Appendix IV, fig. IV.2). In contrast, sample M.1 from the middle of the woollen mitten had almost no contamination. The wool fibres appeared completely



Fig. 9 - the two woollen objects from the BZN8: the lining (left) and the mitten (right).

smooth with only a hint of scaling (Appendix IV, fig. IV7-8). In some fibres the outer cuticle of the wool had disappeared completely, exposing their core of fibrils (Appendix IV, fig. IV.9). Sample M.2 from the bottom edge of the mitten was a little more contaminated, showing small particles and a layer of crust coating the fibres. Here, the scales could be more easily discerned, although they were nowhere near as defined as in samples L.1 and L.2. (Appendix IV, fig. IV.10-11). The mitten showed the same mechanical damage as the lining.

In the case of the BZN8 objects there seems to be an inverse relationship between the presence of scales on the wool fibres (which is an indication the material is worn down) and the amount of contamination. Whether the cleaning of the objects has indeed caused the fibres to be worn down is difficult to tell. The database records of both objects kept by the RCE only mention them being rinsed with tap water, then washed with 'Teepol' (a British brand of household detergents), and finally being dried. Beyond this no further details given, although it is certain the treatments have been carried out by an in-house conservator of the RCE.

The SEM images that were made of the wool of the BZN17 carpet show fibres in a similar condition as sample M.2. The scales of the cuticle can still be seen, but they are not as clear-cut as the scales in samples L.1 or L.2. However, not all fragments were sampled. Given the results of the BZN8 object it is likely that fragments in a different state of contamination (for instance XI and XIII) would yield different images when analysed with SEM. This would support the idea that rinsing an object influences its condition.

4.3 Factor: Materials

One inevitable factor contributing to an object's condition are the characteristics of its materials. Each material, whether natural or manmade, has its specific strengths and weaknesses when it comes to deterioration. In the BZN17 carpet the main materials are wool and silk. Although both made of animal protein, wool and silk display very different properties.

The morphology of both fibres is one such difference: silk consists of a single smooth fibre of even thickness along the whole length, whereas wool is made of shorter fibres which taper towards the end and are covered with scales. These scales are the reason for the phenomenon of felting: mechanical action rubs fibres together causing the scales to grab on to one another, creating a densely matted surface. In the case of the BZN17 carpet the mechanical action provided by the currents of the Waddenzee may have been the reason for the matting of the pile. In addition to this, the scales also provide a rough surface for contamination to cling to. This can also be observed in the BZN17 carpet: the pile shows much more severe contamination than the silk ground (Appendix III, fig. III.5).

The difference in swelling of fibres when exposed to moisture is another contributing factor. The amount of swelling depends on the proportion of amorphous regions in the fibre and how well the fibre is able to retain the moisture due to hydrogen and dipole bonding. Silk, which is relatively crystalline, will swell up to 19% in the transverse direction. Wool, which is much more amorphous, may swell up to 40% under the same conditions.[76] These different rates of swelling can create internal stress within an object, especially in one like the BZN17 carpet where the woollen pile is already densely packed. The built-up stress from the swelling of the wool may not have torn the carpet apart directly, but it will have contributed to weakening the object to external mechanical forces.

Resistance to attack by microorganisms is another discerning characteristic. Wool is built up of a core of fibrils, wrapped in a thick outer layer, the cuticle. To a certain extent this cuticle, in which disulphide links are abundant, protects the fibre from deterioration. These disulphide links can be ruptured by oxidation, creating sulphonic acid which in turn can catalyse hydrolysis of the peptide bonds in humid conditions. This leaves the inner core vulnerable to attack.[77] In addition the scales on the cuticle provide a place for attacking microorganisms to nestle in. The smoothness of the silk fibre provides no such shelter. The closely packed crystalline structure of silk offers much better protection against enzymes made by attacking organisms. Under the same conditions, silk

[76] Due to the hydrophilic nature of wool fibres the speed at which they will swell is also much greater than that of silk. Tímár-Balázsy & Eastop 1998: 45-51.
[77] Florian 2014: 32-37.

will be able to withstand biological deterioration for a much longer time than wool.[78] The possibility of bacterial attack of the BZN17 carpet is further discussed in chapter 5.

One final notion on the materials of the BZN17 carpet: the object may very likely not have been new when the ship sank. Based on its stylistic characteristics the carpet was presumably created in the second half of the 16th century. The ship in which it was found is thought to have sunk around the second quarter of the 17th century, after 1636. This means that at this point the carpet could have been as much as 75 years old, possibly more.[79] One clue that the object had been in use for a while is in the infill visible on fragment XIII (see Appendix II, fig. II.3). Made in a technique and material different to the rest of the object, this could possibly be a later addition meant to repair a hole or tear in the carpet. While high-quality carpets may remain in good condition for years, this previous exposure to light, humidity and the wear and tear of use may have negatively affected the condition of the object's fibres, even before it was lost to the sea. The influence of light especially is detrimental to any textile fibre. In wool exposure to sunlight causes scission of the protein chain, resulting in loss of breaking strength. Additionally, the formation of crosslinks lowers the flexibility of the fibres, causing brittleness. These processes have noticeable consequences after as little as 200 hours of irradiation. [80] The same chain scission and cross-linking occurs when silk is exposed to light, but due to the more crystalline nature of the material the effect take longer to have an impact on the integrity of the fibre.[81] The age of the fibres of the BZN17 carpet will have made it more susceptible to other forms of damage and deterioration.

4.4 Factor: treatment

Salvage

The conditions underwater at the time of the salvage of the carpet were such that the divers relied only on their sense of touch during the search for objects. At this time it was not yet known that the BZN17 contained textiles. Both of these facts have led to the salvage of the carpet being rougher than recommended for textile objects. Objects are advised to be brought up supported on a horizontal surface, together with the sediment they are found in. The object should remain supported in this manner until it can be dried.[82] In the case of the BZN17 carpet the fragments were pulled in clumps from the sediment and placed in the diver's net. While submerged in water wool can take up as much as 200% of its weight in moisture.[83] This makes aged fibres like that of the carpet especially vulnerable to mechanical damage. It is very likely that the BZN17 carpet was

[78] "The highly crystalline regions make silk fibres mechanically very strong and resistant to chemical agents. Under similar conditions wool, which is highly amorphous, may degrade completely." Tímár-Balázsy & Eastop 1998: 45.
[79] See note 74.
[80] Weatherall 2001: 119-21
[81] Miller & Reagan 1989: 104-7.
[82] Jones et al. 2007: 9-11.
[83] Tímár-Balázsy & Eastop 1998: 51.

severely damaged when it was pulled from the sediment. It is not unthinkable that the object had been one single piece up until the point where it was salvaged and torn into fragments. The fragments that were not immediately rinsed were transported wet in a plastic bag. This would have allowed for fragments to rub along each other, causing further mechanical damage.

Rinsing

As many objects pulled from a marine environment are covered in soil rinsing with water is often used to clean them. But the consequence of this common practice can be quite detrimental to the object's condition. As mentioned previously the added weight of the water absorbed into the fibre makes the objects more vulnerable to mechanical damage. Many conservators recommend aqueous cleaning only when the object is fully supported inside the basin by means of sheets or netting. Non-ionic detergents may be used; but to make sure no residue stays behind the object must be thoroughly rinsed with deionised water.[84] The whole process requires extensive handling of the object.

Some conservators reject aqueous treatment altogether, pointing to the irreversible changes to the object's condition that are caused by soaking and rinsing. One study in particular highlights the damage done by rinsing as opposed to freeze drying and dry cleaning. The samples rinsed with water were found to have soil particles more deeply imbedded, their dyes washed out, and many of their scales missing or worn down.[85] The latter two consequences can also be observed in the BZN17 carpet. The loss of dye due to prolonged exposure to water is particularly evident in fragment XII and XIII. Where most fragments were briefly rinsed and then left to dry, these two were left to soak in water for up to a week, resulting in almost complete loss of colour. When looked at using SEM the wool fibres also do not show the well-defined scales that can be seen in the lining of the BZN8 mitten (Appendix IV, fig. IV.6). This suggests the scales have been worn down by mechanical action, although it is difficult to determine whether this was caused by the rinsing or by other movement such as the currents of the Waddenzee.

Drying

To dry a wet textile object, whether cleaned or not, it can simply be exposed to air to let the water evaporate from the fibres. This process causes physical tension within the object, potentially leading to shrinking and embrittlement.[86] Water forms hydrogen bonds with the fibres, which are disrupted during the evaporation. Using a less polar liquid such as ethanol as an intermediary prevents this from happening. Wool especially

[84] Victoria Jenssen even goes as far as to recommend additional mechanical cleaning by means of brushing or sponging the object while it's soaking to better remove any contaminations. Jenssen 2014: 141.
[85] Ringgaard 2011: 4-5.
[86] Jenssen 2014: 123.

reacts better to this type of treatment.[87] Solvents must however be chosen carefully as they themselves may negatively affect the condition of the fibres.[88]

The speed at which the drying takes place can be influenced by the ambient temperature and relative humidity and the air flow in the space. Regardless, different materials will still dry at a different rate. At a temperature of 21°C with 65% relative humidity, it takes silk 39 days to reach an equilibrium state with its surroundings when starting from a completely wet state. Wool will take as much as 109 days.[89] Conditions in the attic where the fragments were dried were presumably dryer and warmer (being a room on the top floor during summer). Although the drying time will have been shorter because of this, it raises the question whether the fragments were truly dry when they were packaged after three weeks. Moisture may still have been present in the wool fibres. If water is indeed harmful to the condition of the BZN17 carpet the wool will have been exposed to it much longer.

Storage

When objects are stored they should be protected from light, dust and physical stress. Ideally, the storage would also prevent the need for direct handling. The two methods by which the fragments have been stored (first in envelopes with filtration paper, now the custom-built storage box) meet the first three requirements, although arguably the envelopes will not have provided as much support as the stiff cardboard sheets the fragments are currently on. If the object is kept in storage in its current box it should not suffer any further damage. However for examining the object from both sides it is still necessary to handle the object. Fragments have to be flipped manually which results in a loss of fibres, especially that of the pile (as is indicated by fine coloured dust left behind when a piece is moved). In this sense the current storage box is inadequate and contributes to the continuous deterioration of the fragments.

[87] An experiment showed better results in terms of flexibility and tensile strength for dried wool samples first rinsed in 100% ethanol as opposed to samples rinsed only in water. Tarleton & Ordoñez 1995: 90-91.
[88] Jakes & Mitchell 1992: 344.
[89] Tímár-Balázsy 1999: 664.

5. Sulphur-utilising bacteria hypothesis

Having discussed the factors that may have contributed to the condition of the BZN17 carpet, this chapter will expand upon one of the aspects of the environmental factor: the bacteria that are present within marine sediment. The idea that sulphur-utilising bacteria may be the cause for the poor state of the carpet's wool came about when questioning the reason for the difference in condition of the ground weave and the pile. One of the suggestions offered, courtesy of Dr Han Neevel of the RCE, was that attacking bacteria may favour wool over silk, causing it to deteriorate at a faster rate.

Before delving into the contents of this chapter, is it important to first discuss its title. The name 'sulphur-utilising bacteria' is not a proper scientific term. It was chosen by the author to encompass the many different types of bacteria which in some way use sulphur or its derivatives such as sulphate or sulphide to obtain their energy. The main focus will be on the group of sulphate-reducers, as it is this type of bacteria that is most commonly found in the anoxic environment of the sea floor. This chapter touches on many complicated issues that can only be superficially discussed. The author is aware that the pictured painted is only a very simplistic reflection of a much more complex reality.

5.1 Chemistry of Wool and Silk

To understand why sulphur utilising bacteria may play a role in the deterioration of the BZN17 carpet, the chemical nature of wool and silk must be discussed. These fibre types share some of their main characteristics, being both made of protein. Protein fibres tend to be moderately resistant to acidic conditions, have good elasticity, and retain heat rather than conduct it. At a molecular level proteins consist of amino acids linked through peptide bonds into long chains. These chains form complex primary, secondary and tertiary structures dependent on the types of amino acids, their sequence and proportion, and the intermolecular bonds they form. These factors also determine the specific characteristics of different proteins.[90] It is at this molecular level that the first differences between wool and silk become apparent.

Wool

Like any other animal hair, wool is made predominantly of α-keratin. The variations in wool of different species are for the most part caused by the thickness and morphology of the hair, not by its molecular make-up. The main amino acids in keratin are serine, arginine, cysteine and glutamic acid. The size of the latter three forces the chain to take on a helix shape with the side groups projected outwards. Hydrogen and disulphide bonds are formed within the helix itself, and with neighbouring chains. Due to the large size of the side groups only a small percentage of α-keratin is crystalline. The amorphous areas of keratin are vulnerable to deterioration, but are protected to some extent by the disulphide bonds. The cysteine is mainly present in the form of cysteine, which is a dimer

[90] Tímár-Balázsy & Eastop 1998: 36-42.

form of the amino acid connected through a disulphide bond (fig. 10).[91] On average keratin contains 10% cystine, giving wool a sulphur content of between 2.5 and 5%.[92]

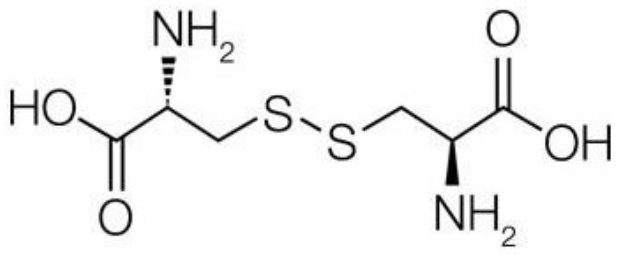


Fig. 10 - Line structure of the cystine molecule.

Silk

Although other animals may also produce silk (such as spiders), it is generally the cocoon of the silk moth that is referred to when mentioning silk. The caterpillar spins its cocoon of a single long thread made from two strands of fibroin encased in sericin. The gum-like sericin is boiled off during processing, leaving just the smooth fibroin. This is composed mainly of glycine, alanine and serine. In contrast to keratin, fibroin contains only 0.2% cysteine, making its sulphur content <0.1%. Due to the high percentage of amino acids with small side groups the peptide chains of fibroin are relatively straight and can be arranged in tightly packed β-pleated sheets. This compactness lends fibroin a high degree of crystallinity. Apart from giving it sheen, the pleated sheets make the silk fibre strong and resistant to attack. Silk may still be penetrated through its amorphous regions.

5.2 The Different Sulphur-Utilizers

As mentioned, there are many different bacteria which may utilise sulphur, both aerobic and anaerobic. Both types use redox reactions to gain energy. A redox reaction is one in which one or more electrons are transferred from the reductant to the oxidant. The energy gained from the reaction is used by bacteria for the maintenance of their cells, or for cell division.[93] Below, three types of sulphur utilising bacteria that may be found in the marine environment are described.[94] These bacteria are all part of the natural sulphur cycle in seawater, in which the various compounds of sulphur are continuously reduced

[91] α-Keratin is formed into a tight helix, creating the hard material seen in hair, hooves and nails. Even harder is β-keratin, which is pleated into sheets, and is found in scales and shells. This configuration has a much higher degree of crystallinity. The γ-configuration of keratin, a wider helix than the α-configuration, is much softer and found in skin cells. Tímár-Balázsy & Eastop 1998: 48.

[92] The Textile Institute 1986: 9.

[93] Zehnder & Stumm 1998: 12.

[94] Many more sulphur-utilising bacteria exist outside the marine environment, such as the thermophiles which may be found in volcanic lakes and hot springs, bacteria found in the soils that degrade dead organic material, and the bacteria found in the rumen of animals that aid with digestion.

and oxidised (fig. 11). This cycle is not a closed system. Sulphur is added through decomposing organic material and dissolving mineral deposits. Sulphur may leave the cycle through mineralisation or the formation of ferrous sulphides.[95]

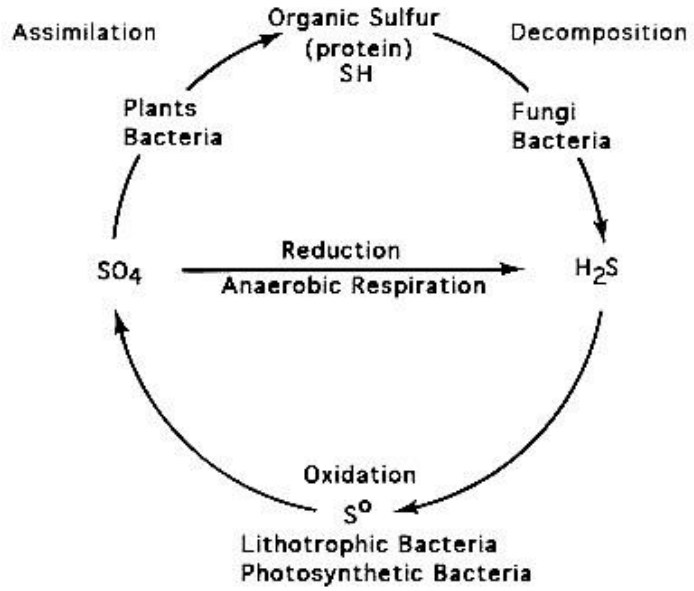


Fig. 11 - Schematic representation of the natural sulphur cycle. (Author's note: SO_4 should be SO_4^{2-}).

Oxidisers

These bacteria use reduced sulphur compounds such as sulphides as an electron donor, producing sulphate through oxidation. In the marine environment they are found in the water and in the top most layer of sediment where oxygen is still present. Most oxidisers are aerobic, requiring oxygen to perform the redox reaction. Some bacteria however, such as the group of 'purple sulphur bacteria', are anaerobes, and require sunlight instead of oxygen. The oxidation process consists of multiple steps, which vary per species of bacteria. The net aerobic reaction is as follows: [96]

$$H_2S + 2O_2 \rightarrow SO_4^{2-} + 2H^+$$

Sulphate-reducers

Collectively named *Desulf-*, sulphate-reducing bacteria are a large and varied group whose common denominator is their ability to reduce sulphate to gain energy.[97] They are anaerobic, although some species may tolerate low concentrations of oxygen. As such they are mostly found in the sediment or deeper levels of water. They require an organic

[95] Widdel 1988: 546-47

[96] All of the reactions in this paragraph were taken from *table 1.5* in Zehnder & Stumm 1998: 26.

[97] This groups encompasses the genera *Desulfobacterales, Desulfovibrionales, Desulfotomaculum, Desulfosporomusa*, and *Desulfosporosinus*, as well as the distinctly named *Syntrophobacterales*. Widdel 1988: 474.

substrate and dissolved sulphate to perform the following reaction:

$$2H^+ + SO_4^{2-} + 2(CH_2O) \rightarrow H_2S + 2CO_2 + 2H_2O$$

Sulphur reducers

This small group of bacteria is able to reduce elemental sulphur as a means of gaining energy. They are found in marine environments where the reduction of sulphate also yields sulphur rather than just (hydrogen) sulphide. In areas shallow enough to allow light to fall on the sediment, sulphur reducers form a syntrophic relationship with green sulphur bacteria that use photosynthesis to turn (hydrogen) sulphide into sulphur. Sulphur reducers may yield their energy through two different reactions:

$$2S^0 + (CH_2O) + H_2O \rightarrow 2HS^- + CO_2 + 2H^+$$

and:

$$S^0 + H_2 \rightarrow HS^- + H^+$$

5.3 Sulphur in the Marine Environment

When looking at any sedimentary environment, including the sea bottom, two areas can be distinguished: the oxic (concentration of $O_2 \geq 10^{-6}$ molL^{-1}) where aerobes live, and the anoxic ($O_2 \leq 10^{-6}$ molL^{-1}), domain of the anaerobes. The forming of a stable anaerobic underwater environment is the result of both the limited access of oxygen due to its slow diffusion into water, and the constant fermentation of organic material on the sea floor. Due to the high levels of microbial activities, oxygen depletes quickly in the upper few millimetres of the Waddenzee sediment. Below, the sediment is an anoxic environment.[98]

Sulphate is very common compound found in both the water and the sediment, with a global average of 28 mmol or 2.7 g per litre.[99] It is relatively inert, and nontoxic to the environment. Reduction of sulphate takes place in the anoxic part of the sediment, where it is transformed into hydrogen sulphide. The net reaction is as follows:

$$2(CH_2O) + SO_4^{2-} \rightarrow 2HCO_3^- + H_2S$$

In contrast to sulphate, hydrogen sulphide is toxic to plants and animals. It reacts with iron creating ferrous sulphide which blackens the sediment, and gives of the distinctive smell of rotten eggs.[100] The colour and the smell of the bundles of carpet fragments that were pulled from the BZN17 can probably be explained by the presence of hydrogen sulphide. As an acid, it catalyses the hydrolysis of polymers, and as such plays a role in the degradation of proteins such as keratin. Additionally, hydrogen sulphide may corrode

[98] Köpke et al. 2005: 7819.

[99] Compare this to the concentration of oxygen in the water, which is 0.28 mmol of O_2 per litre for water saturated with oxygen from the air. Or 1.34 mmol of O_2 per litre for water saturated with oxygen from photosynthesis. Widdel 1988: 519-20.

[100] Widdel 1988: 471.

metals through oxidative reactions. It may therefor also have aided in the degradation of the metallic threads of the BZN17 carpet.

5.4 Bacterial Attack of Keratin

While sulphate-reducing bacteria are found in the anaerobic sediment, they are generally not able to degrade macro polymers, which include proteins such as fibroin and keratin. Instead, these bacteria feed on the fermentation products created by other organisms. In this sense these bacteria are scavengers. The degradation of proteins is a complex process in which multiple organisms are involved. The polymer is hydrolysed step-by-step first to peptides and then amino acids. It is only when the sulphur is separated from the amino acid, and oxidised by another organism, that most sulphate-reducing bacteria are able to use it. [101] The presence of sulphate-reducers is therefore usually not the cause for the degradation of proteins such as wool, but merely a consequence of the process.

There are however some exceptions known of sulphate-reducers who are able to use amino acids directly. Analysis on the sulphate-reducing bacteria found in the sediment of Tokyo Bay showed they could indeed utilise pure amino acids. By measuring the rate of removal of individual amino acids it could be determined that the bacteria preferred to use glycine and glutamate as a substrate, followed by alanine, valine, serine and proline.[102] Glutamate is one of the main amino acids found in keratin, and serine is found in both fibroin and keratin. Sadly this study does not mention which species of sulphate-reducing bacteria dominate in Tokyo Bay and a comparison can therefore not be made to determine if these bacteria also inhabit the Waddenzee.

If attack by sulphate-reducing bacteria is indeed the cause for the poor condition of the carpet, it appears that they prefer wool over silk as a substrate. It is likely that this is due to the difference in cysteine content of both proteins. In an older study an unidentified *Desulfovibrio* sp. were observed to utilise both cysteine and cystine as an energy source. This genus is found in marine environments with high levels of organic material.[103] Again, the exact species was not identified. The mechanisms behind use of cysteine by sulphate-reducing bacteria where covered in a different study. Certain species of *Desulfovibrio* were found to produce enzymes such as desulfhydrase, cystathionase and trypthophanase, which can be used to hydrolyse amino acids such as cysteine.[104] It is not unthinkable that the particular species of bacteria mentioned above are also present in the sediment around the BZN17. Thus it may still be possible that the wool of the carpet was attacked by sulphate-reducing bacteria directly. More often however, much

[101] Fors 2008: 20.

[102] Takii 2003: 333.

[103] The research that observed this behaviour this was done by J.C. Senez and J. Leroux-Gilleron in 1948. Follow-up research was done by A.J.M. Stams, T.A. Hansen and G.W. Skyring in 1985. They found while some amino acids were good substrates for two speciess of *Desulfovibrio*, cysteine yielded only slow growth. Widdel 1988: 498.

[104] The focus of this study was one particular species, *D. desulfericans*, found in the rumen. Although this is of course a very different from the marine environment, the basic mechanisms of these bacteria, anaerobic sulphate reduction, remain the same. Forsberg 1980: 455.

faster-growing fermenting bacteria will prevent sulphate-reducing bacteria from developing on amino acids. When cysteine is fermented it produces pyruvate (CH_3COCOO^-, the conjugated base of pyruvic acid), ammonia, and hydrogen sulphide.[105] As the sulphur in hydrogen sulphide is a compound in a reduced state of -2, it cannot be readily used by sulphate-reducing bacteria. Oxidation would first have to be done by organisms such as above mentioned oxidisers.

The idea that sulphate-reducing bacteria are not responsible for the deterioration of wool is affirmed by Dr. Henk Bolhuis, senior scientist from the department of Microbiology & Biochemistry at the NIOZ. He confirms that this type of bacteria would rely on another organism to break down the keratin for them, as they lack the means to attack complex molecules themselves. As an example of these organisms Bolhuis pointed at the *Actinobacteria,* a genus of bacteria which may be found in both marine and terrestrial environments.[106] Their behaviour resembles that of fungi: they grow in colonies and form mycelia, and aid in the decomposition of organic material. Some strains are able to produce keratinase, an enzyme which is able to decompose keratin by attacking the disulphide bond. Even then, it is only the more amorphous upper layer of the wool fibre that is degraded by *Actinobacteria* in this manner, leaving the core of the fibre intact.[107] If these particular species are present in the waters of the Waddenzee, they are likely the main cause for the deterioration of the wool in the BZN17 carpet. With the keratin broken down other organisms would be able to decompose the protein into smaller pieces. Any sulphate-reducing bacteria would merely be feeding on the final degradation products.

5.5 Bacteria in the Waddenzee

Now that the mechanism of keratin degradation is described, and the bacteria that may use amino acids as a substrate directly are known, is it possible to determine whether bacterial attack has indeed played a role in the poor state of the BZN17 carpet? For this, the exact species of bacteria that live in the Waddenzee must be compared to those mentioned above. The many microclimates within any marine environment make it nearly impossible to find a single study which covers all possible bacteria. So far studies have covered only specific habitats: one looked at bacteria just above the sea floor, the other focussed on bacteria several meters deep inside the sediment layer. The former study sampled 51 cultures of bacteria, none of which were identified to belong to the *Desulfovibrio* genus. However, five genera of *Actinobacteria* were found.[108] Several species were also found by the latter study, in which 112 cultures were sampled. In addition to the *Actino*- bacteria the results also showed seven genera of sulphate-

[105] Pyruvate in turn may be further fermented into lactate, the conjugated base of lactic acid. McInerney 1988: 399-400.
[106] Bolhuis 2017, personal communication.
[107] Tímár-Balázsy & Eastop 1998: 55.
[108] Grossart et al. 2004: 390.

reducing bacteria from the *Desulf-* genus.[109] Plotted against the depth where these species were found results showed that each operated at a different preferred depth, from right underneath to surface up to five meters down. In contrast, the *Actinobacteria* were mostly found in the first 50 centimetres below the surface.

Both studies took their samples in the German part of the Waddenzee. It remains to be seen whether the sea southeast of Texel hosts the same species of bacteria. What does seem certain is that the Waddenzee hosts many different species of bacteria that can either produce keratinase, or reduce sulphate, and can therefor play a role in the condition of the carpet. Although the BZN17 had been buried under sand several meters high, the textile finds were done just below the sediment surface. It seems likely that species of *Actinobacteria* were active around the objects, including the carpet.

[109] Identified where: *Desulfuromonas palmitatis, Desulfovibrio acrylicus, Desulfovibrio aespoeensis, Desulfovibrio zosterae, Desulfovibrio senezii, Desulfobacterium catecholicum, Desulfosporosinus auripigmenti*. Köpke et al 2005: 7824-25.

Conclusion

What are the factors that have contributed to the poor condition of the BZN17 carpet?

This thesis studied different facets of the carpet, including its historical context and the treatment it received during and after salvage. The condition of the individual fragments was then looked at more thoroughly, in an effort to find a correlation between the state of a fragment and the treatment it received. Finally one of the alternative possibilities for the poor condition of the fragments, attack by sulphur-utilising bacteria, was explored.

Context

Based on its material and its stylistic properties, the BZN17 can be presumed to belong to a particular subtype of this group, the so-called 'Herat' carpets. During the 16th century its design with palmettes, narrow vines, and animals are characteristic for this style. Some elements however, such as the cartouches of the main border, deviate from the Herat style. Attribution therefor remains uncertain. The combination of the expensiveness of the silk ground weave and the metal thread accents with the high density of the wool pile suggest this would have been a high-end product.

The conclusions drawn by the earlier publication on the BZN17 carpet differ from what has been found in this thesis. The results by Hartkamp-Jonxis & Smit are based on the similarity in animal motifs to the Fremlin carpet, made mid-17th century in India. Although similar types of animals can indeed be seen on this carpet, any other comparisons fall flat.

Treatment

The BZN17 carpet fragments were discovered in the summer of 2014. They were pulled from the middle area (where supposedly the cargo was kept) of the wreck by the Diver in several bunches. It is likely that the carpet has been damaged during the salvage, although this cannot be determined undoubtedly. The salvaged bunches were covered in black soiling, and it was only when they were pulled upon the ship that the crew was able to determine they consisted of textiles. Two fragments (I and II) were rinsed immediately in buckets of tap water at the clubhouse until fairly clean. Two fragments (XII and XIII) were kept in buckets of tap water for around a week. The remaining fragments (II through XI) were taken home by the Diver while still wet. There the pieces were rinsed in tap water, and pulled apart from each other (with the exception of fragment XI). They were then dried on filtration paper in a warm room, without exposure to direct sunlight. Fragments I and II were kept in a photo frame for some time, the other pieces were kept between sheets of filtration paper in cardboard folders. Afterwards the pieces were handed to the RKD where the object was handled and photographed and stored in a custom-built acid-free storage box. The object was then returned to the Diver in this box, brought to Texel where it stayed at both Museum Kaap Skil and the clubhouse, and finally given into the custody of the State and brought to the Ateliergebouw in Amsterdam.

Condition

The condition of the individual fragments has been assessed in terms of colour intensity, amount of contamination, and amount of remaining pile. While the amount of contamination varies greatly between fragments, there is an inverse relationship between the amount of rinsing or soaking a fragments has received and the intensity of its colours.

Material factors have contributed to the condition of the carpet. Fibre morphology has played a role as wool fibres have protruding scales, which cause the material to be felted by the movement of the sea. The courser surface also holds on to more contamination. Due to the built-up of the fibre silk is more resistant to chemical and microbial attack than wool, making it more likely to survive under the same conditions. The different amount of swelling between wool and silk when submerged in water can cause tension within an object, making the object more susceptible to damage. Finally the age of the fibres and its previous use will also have affected the strength of the object.

The treatment of the fragments has played a major role in the carpet's current condition. It is very likely the object was torn apart during salvage due to its weakened state while wet, combined with the lack of awareness of the divers to the presence of such fragile objects. Rinsing the fragments in tap water may have removed soiling from them, but it will also have caused mechanical damage and loss of material. The loss of colour in fragments XII and XIII can be fully attributed to their prolonged soaking. Air-drying the fragments after rinsing may have caused shrinkage and embrittlement. Additionally, due to the long drying time of wool it may be possible that moisture was still present in the fibres when the objects were packed for storage. The methods of storage itself, both the envelopes and custom box, offer sufficient protection against light, dust, and distortion. However they do not allow for observation of both sides of the fragments, leading to further loss of material each time the fragments will be handled.

Bacteria

Sulphur-containing material such as wool may be attacked by sulphate-reducing bacteria. Due to the complexity of protein molecules, these bacteria would generally not be able to utilise the sulphur from amino acids directly. The polymer would first have to be broken into smaller pieces through fermentation by other organisms. An example of such an organism is the genus of *Actinobacteria*, a group of keratinase producing bacteria which are found throughout the top layer of marine sediment, including that of the Waddenzee. Certain species of bacteria from the *Desulfovibrio* genus have also been found that can utilise amino acids directly. It has not been confirmed that this species is also present in the Waddenzee, but many other species of sulphate-reducing bacteria are.

Whether sulphur-utilising bacteria are the cause for the poor state of the carpet's wool cannot yet be answered. When the BZN17 carpet was found it was covered with only a thin layer of sand. It is probable that both *Actinobacteria* and sulphate-reducing bacteria were active in this environment. While the latter may not have attacked the wool of the carpet directly, it is likely the *Actinobacteria* have. As such it is more likely

that it were the *Actinobacteria* that contributed to the wool's poor state, rather than the sulphate-reducing bacteria. So while the hypothesis that sulphate-reducing bacteria are responsible for the poor state of the wool is untrue, there is reason to assume that bacterial attack has played a role in the deterioration of the BZN17 carpet while it was underwater.

In Short

While many factors may have contributed to the condition of the BZN17 carpet, the treatment of the fragments will have had a larger negative impact than the material properties of the fibres. The latter will have weakened the object through its reaction to the marine environment and aging, which will ultimately have made the carpet more susceptible to damage. However most of the major damage to the object (the tearing of pieces, loss of pile and fading of colours) appears to have resulted from the treatment the fragments received from the point of their salvage onwards.

Recommendations for Future Research

Using literature and comparable objects this thesis was able to establish to some extent the age and origin of the BZN17 carpet. The accuracy of these conclusions are somewhat questionable, even more so because a previous study ended in very different results. Further research by someone with a more thorough understanding of the subject may be able to more definitely establish the time and place where this carpet was manufactured. Additionally, the possibility to create a digital reconstruction should be further explored. This could be done using the border reconstruction from this thesis as a starting point, and comparing the imagery of the fragments to similar, complete carpets.

Although SEM images have already been made of the BZN17 carpet, this was only done from samples of fragments I, IX and X. To better understand whether rinsing has had an effect on the condition of the fragments it would be worthwhile to compare images of fragments I, II and X (which were rinsed immediately), fragments III-IX and XI (which were rinsed several hours after salvage) and fragments XII and XIII (which were left to soak in tap water for a week) with regards to what the scales on the wool fibres look like. Can a relationship indeed be established between longer rinsing or soaking, and a more severe loss of scales?

One fact that has not been taken into consideration by this thesis is the relatively good condition of the black pile compared to the other colours. There is the distinct possibility that the dyestuffs used in the BZN17 carpet play an important role in the ability for the wool fibres to survive. The tannins used for the dark colours in particular may have been able to act as protection against microbial attack.[110]

[110] Scalbert 1991.

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Images

Fig. 1 Detail of a 2013 map of the Waddenzee, created by DataCharter. Source: <http://www.wpgps.com/uploads/1/2/9/1/12911715/_334690_orig.jpg> 26 May 2017.

Fig. 2 Schematic drawing of a Perian or Senneh knot. (Source: <http://www.arearugfacts.com/hand_knotted_rugs.php> 19 May 2017.

Fig. 3 Painting of a Dutchman with a Persian carpet. Abraham van den Hecken, Cornelis Jansz Meyer (1629-1701). Waterbouwkundige, 1650-1655, oil on canvas, 81 x 64 cm, inv.nr. SK-A-1410, Rijksmuseum, Amsterdam. Source: <https://www.rijksmuseum.nl/nl/collectie/SK-A-1410> 21 April 2017.

Fig. 4 Detail from a book illumination showing two men sitting on a Persian carpet. Shaikh Zada, "Interior Reception", folio 36r from a *Bustan of Sa`di*, ca. 1525-35, ink, watercolour and gold on paper, 22.3 x 12.5 cm, inv.nr. 1974.294.3, Metropolitan Museum of Art, New York. Source: <http://www.metmuseum.org/art/collection/search/452671> 20 April 2017.

Fig. 5 Two details from a Persian carpet showing a dragon and a phoenix and cloud-bands. *Silk animal Carpet*, 1550-1600, silk, 241 x 178 cm, inv.nr. 14.40.721, Metropolitan Museum of Art, New York. Source: <http://www.metmuseum.org/art/collection/search/446642> 20 April 2017.

Fig. 6 Detail of the Metropolitan carpet fragment. *Carpet fragment*, late 16th century, woollen pile on silk, 110x125 cm, inv. nr. 1970.302.1, Metroplitan Museum of Art, New York. Source: <http://www.metmuseum.org/art/collection/search/452186> 2 June 2017.

Fig. 7 Detail of the main field of the Fremlin carpet. *The Fremlin Carpet*, ca. 1640, woollen pile on silk, 599x299 cm, inv.nr. IM.1-1936, V&A Museum, London. Source: <http://collections.vam.ac.uk/item/O74043/the-fremlin-carpet-carpet-unknown/> 27 April 2017.

Fig. 8 Photograph of fragment II and X put back together a single piece. Photo by author.

Fig. 9 Two woollen objects from the BZN8, lining and mitten. Woollen lining of a leather mitten, 17th century, knitted wool, 25x19 cm, inv.nr. [MA]BZN8-219. Woollen mitten, 17th century, knitted wool, 24x12 cm, inv.nr. [MA]BZN8-220. Maritiem depot RCE, Lelystad. Source: <http://cultureelerfgoed.adlibsoft.com/search.aspx> 12 June 2017.

Fig. 10 Line structure of the cystine molecule. Source: <https://www.wacker.com/cms/en/products/product/product.jsp?product=9378> 12 June 2017.

Fig. 11 Schematic representation of the natural sulphur cycle. Created by Kenneth Todar. Source: <http://textbookofbacteriology.net/environment_4.html> 28 May 2017.

Appendices

Appendix I Photographs

Appendix II Condition Assessments

Appendix III Hirox Images

Appendix IV BZN8 Mittens

Appendix V Border Design Reconstruction

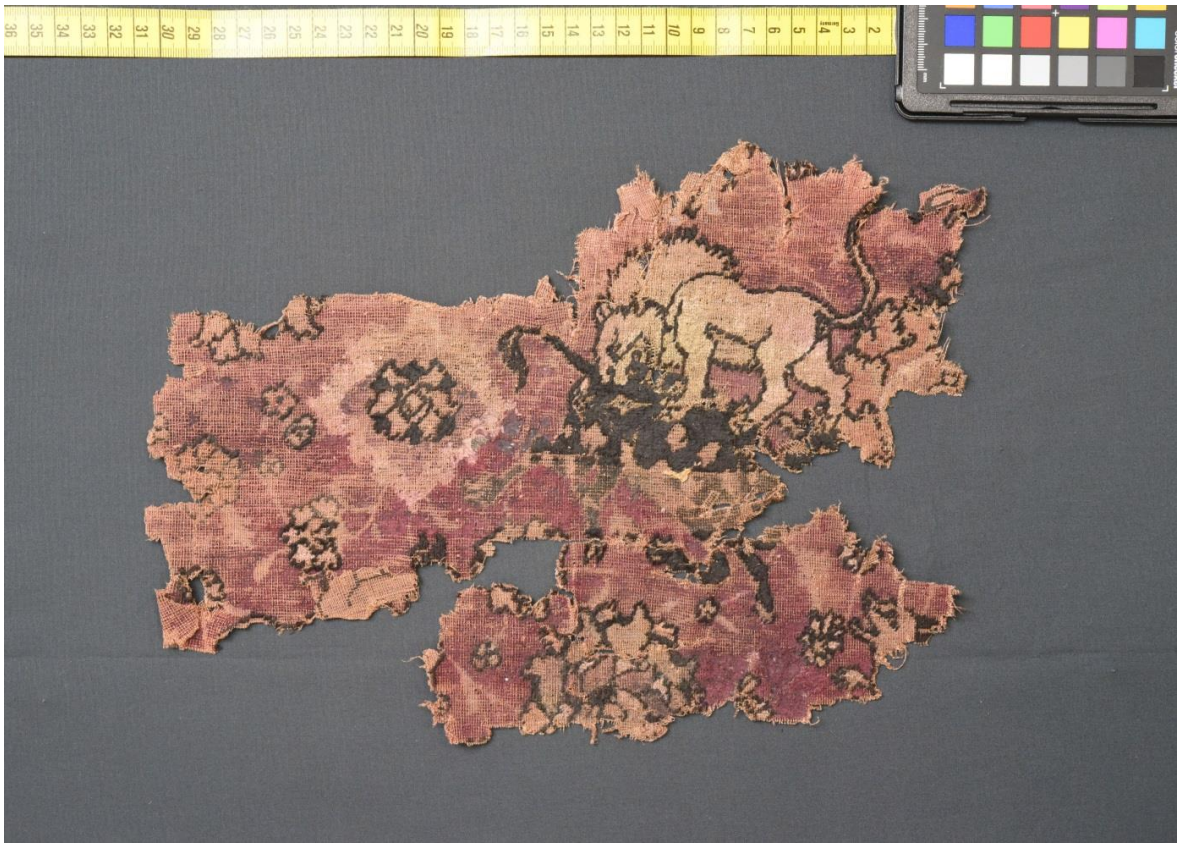
Appendix VI Cultural Context: the Safavids

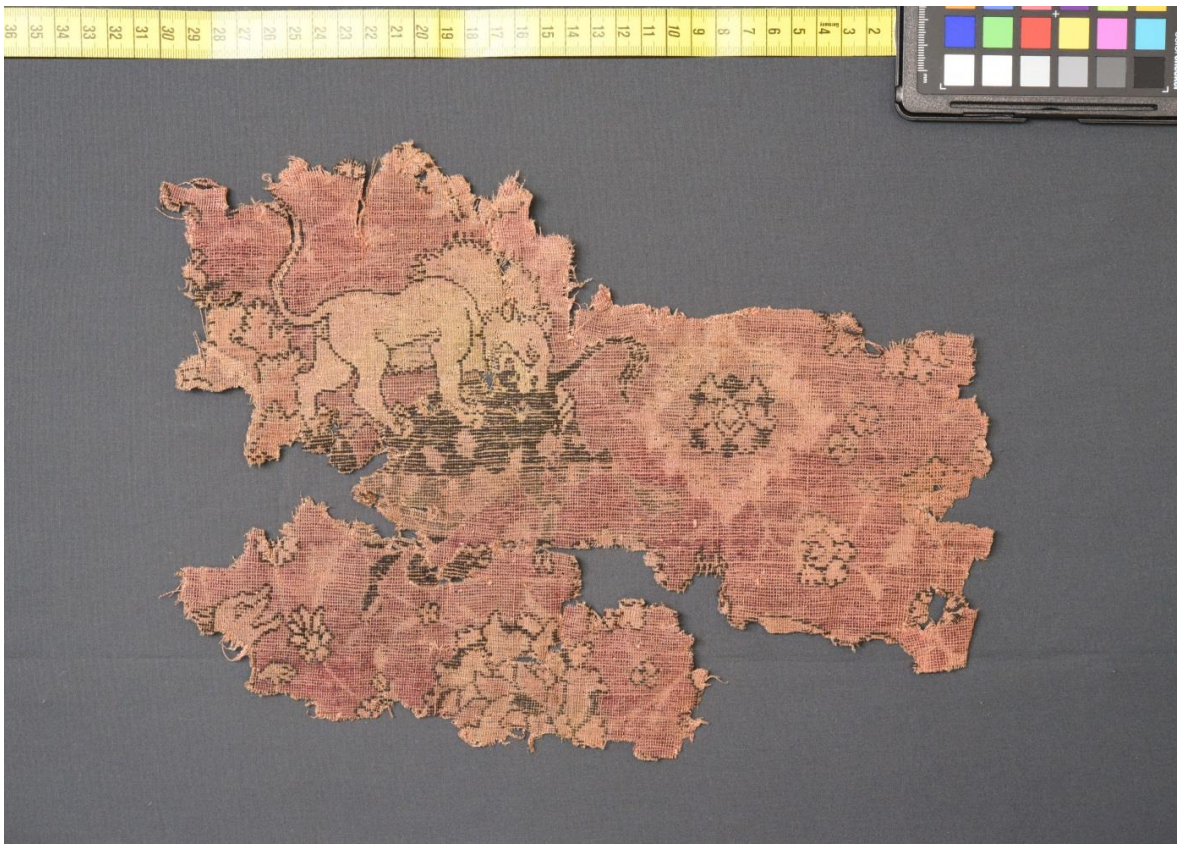
Appendix I - Photographs

The following pages contain photographs of all thirteen fragments of the BZN17 carpet. They have been taken on 18 April 2017 by the author at the Ateliergebouw, Amsterdam. The camera used is a Nikon D750, with a 60mm f/2.8 lens. The photographs have been cropped and white balanced using Adobe Photoshop CC 2015. The fragments have been placed in such a manner that the weft threads run vertically. This is based on fragment XIII, as in carpet weaving the fringe is formed by the termination of the warp threads. The 'top' side of each fragment could not be established, and was therefore chosen either randomly, or based on the direction of its motifs. Thus it is possible that some fragments have been photographed in the wrong direction in relation to their original position in the carpet as a whole.

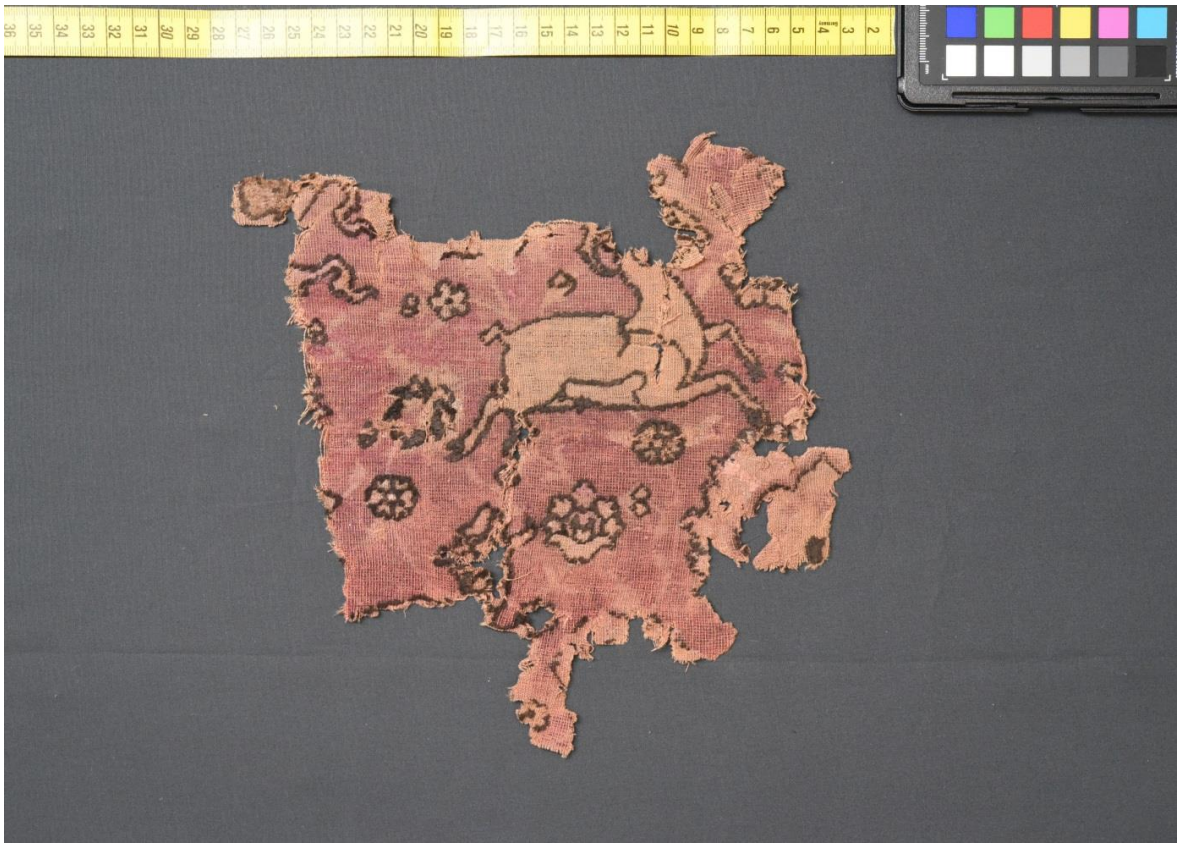
Each fragment has been photographed from the back and the front, the front being in this case defined as the side of the woollen pile. The exception to this rule is fragment XI, which consists of two pieces of carpet stuck together, both with the pile facing outward. In this case the front and back side have been arbitrarily assigned.

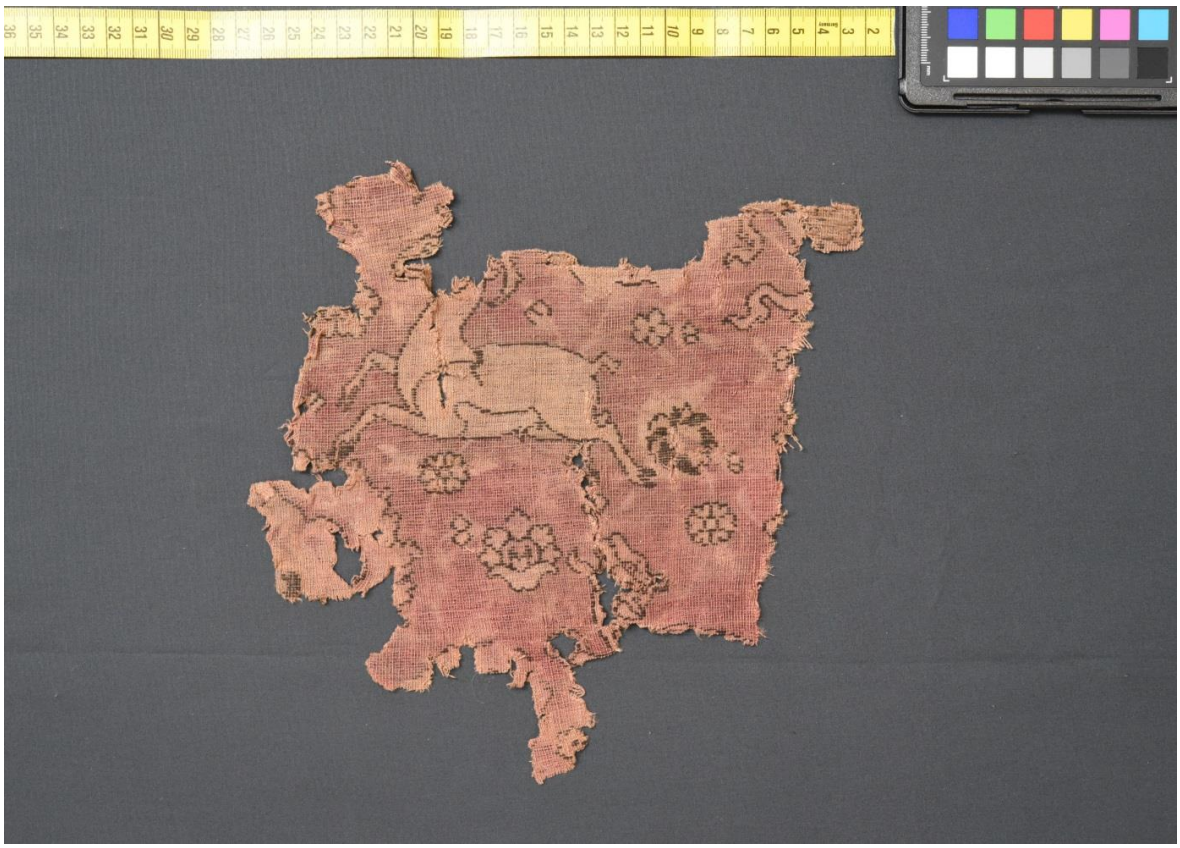
Fragment I - front (above) and back (below).



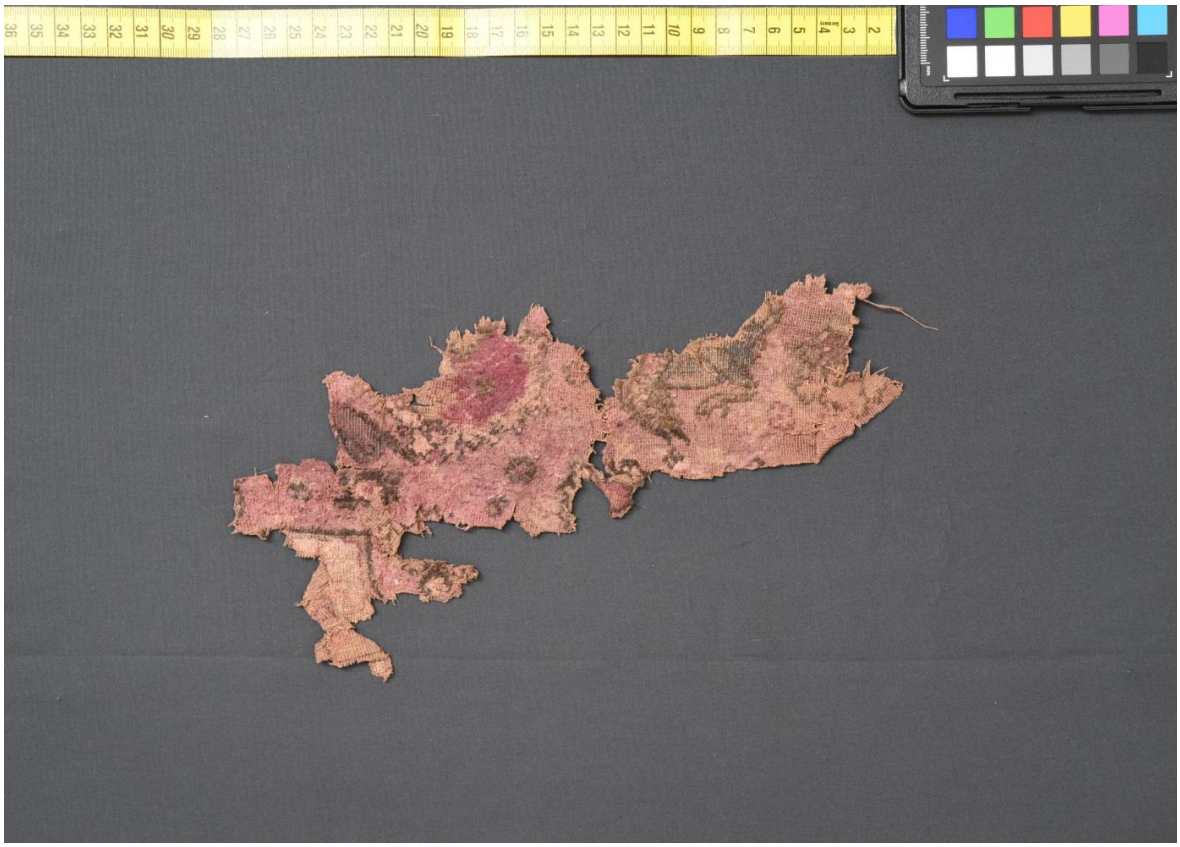


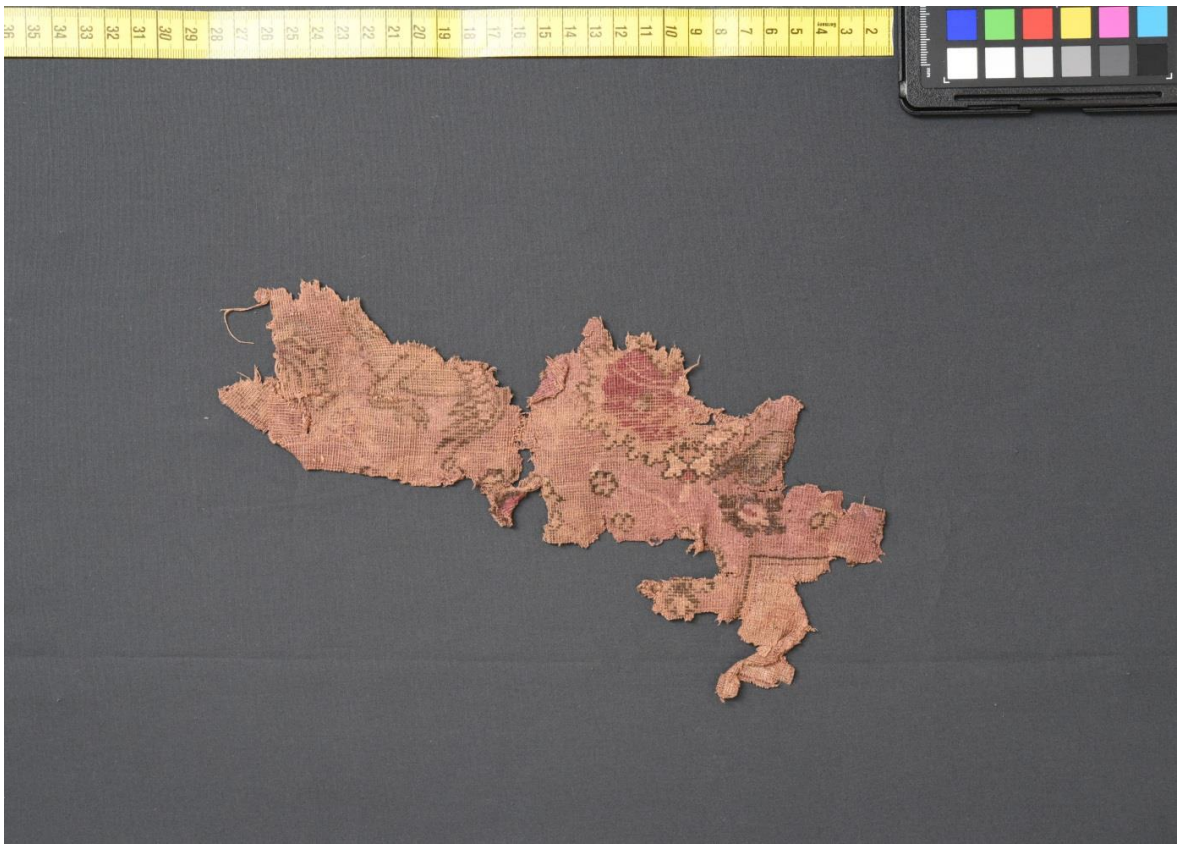
Fragment II - front (above) and back (below).



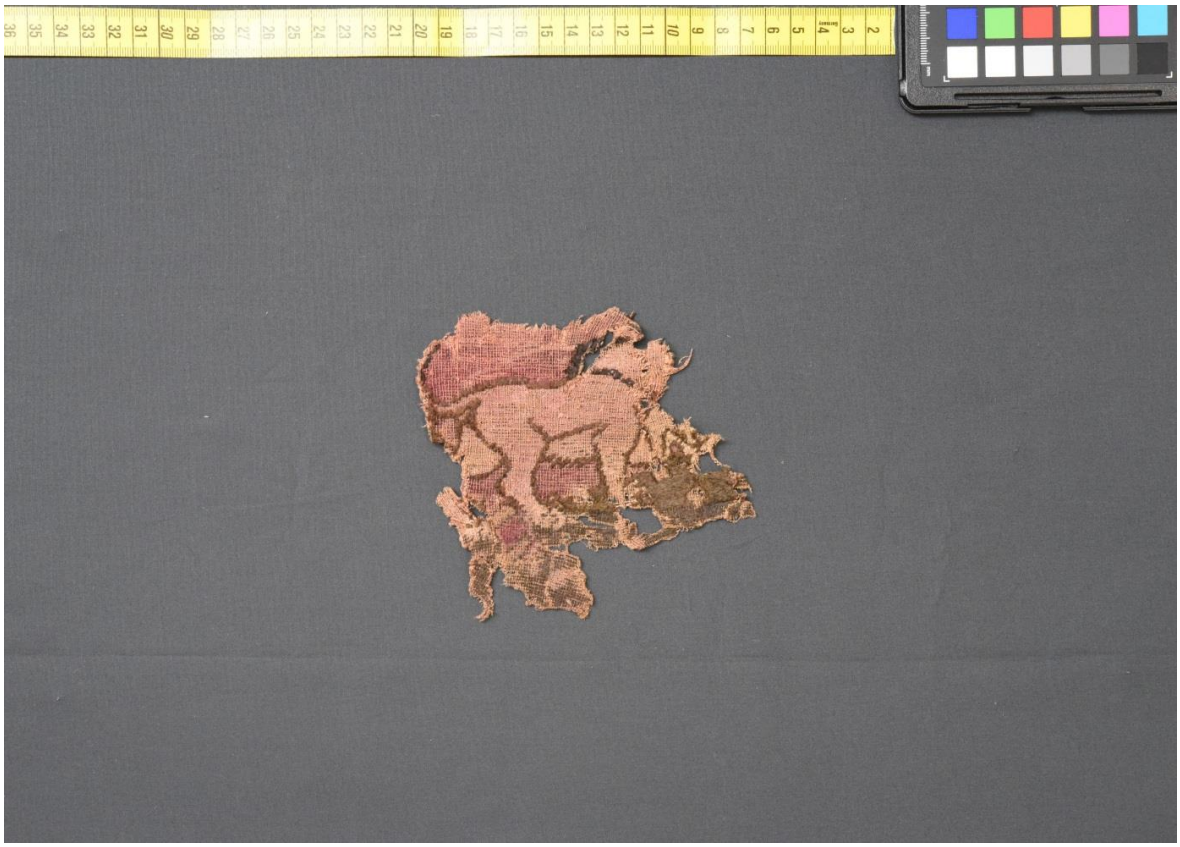


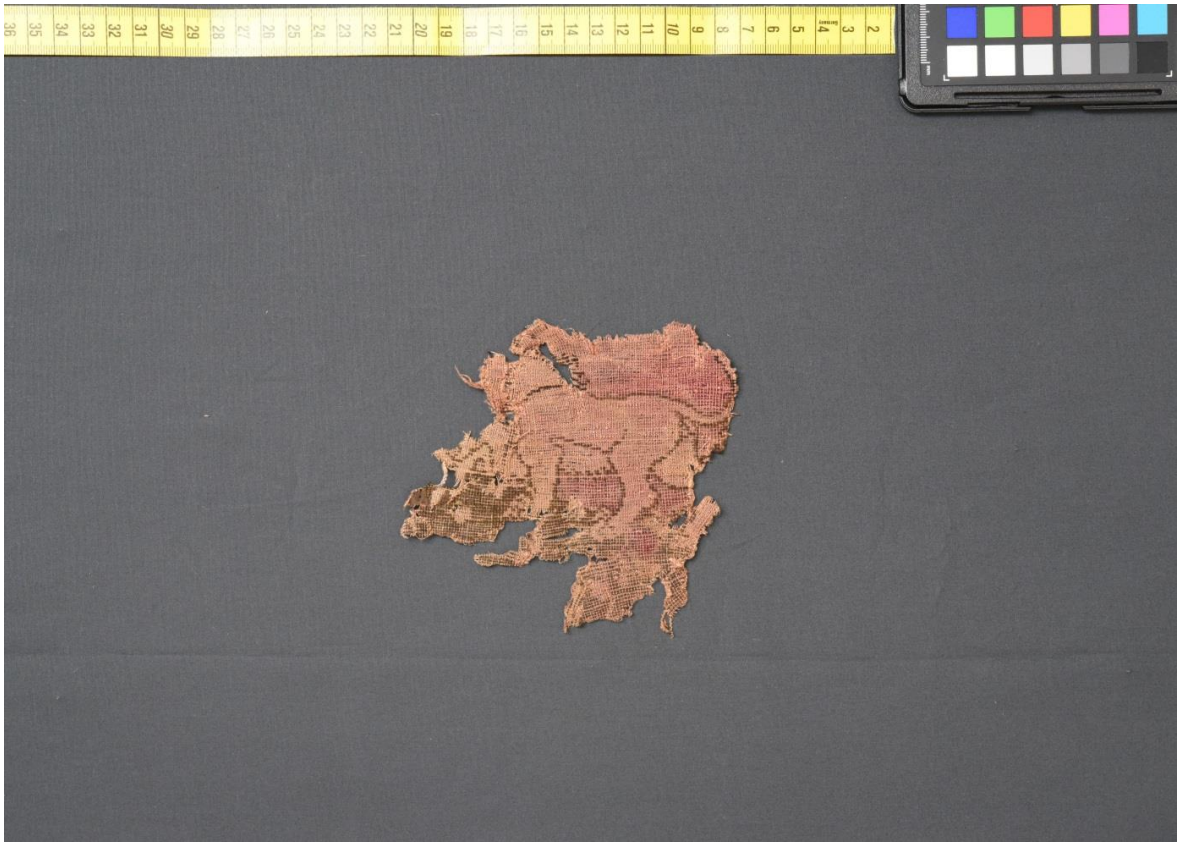
Fragment III - front (above) and back (below).





Fragment IV - front (above) and back (below).





Fragment V - front (above) and back (below).





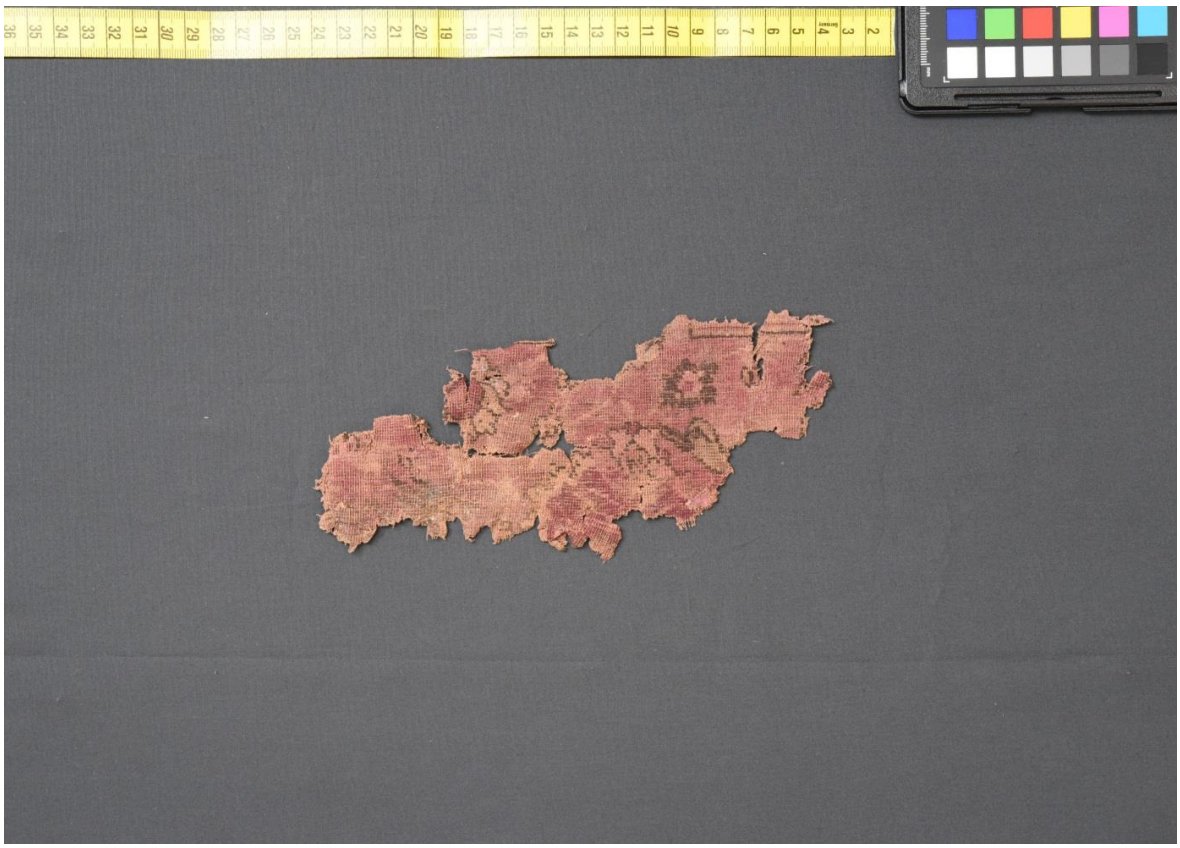
Fragment VI - front (above) and back (below).





Fragment VII - front (above) and back (below).





Fragment VIII - front (above) and back (below).



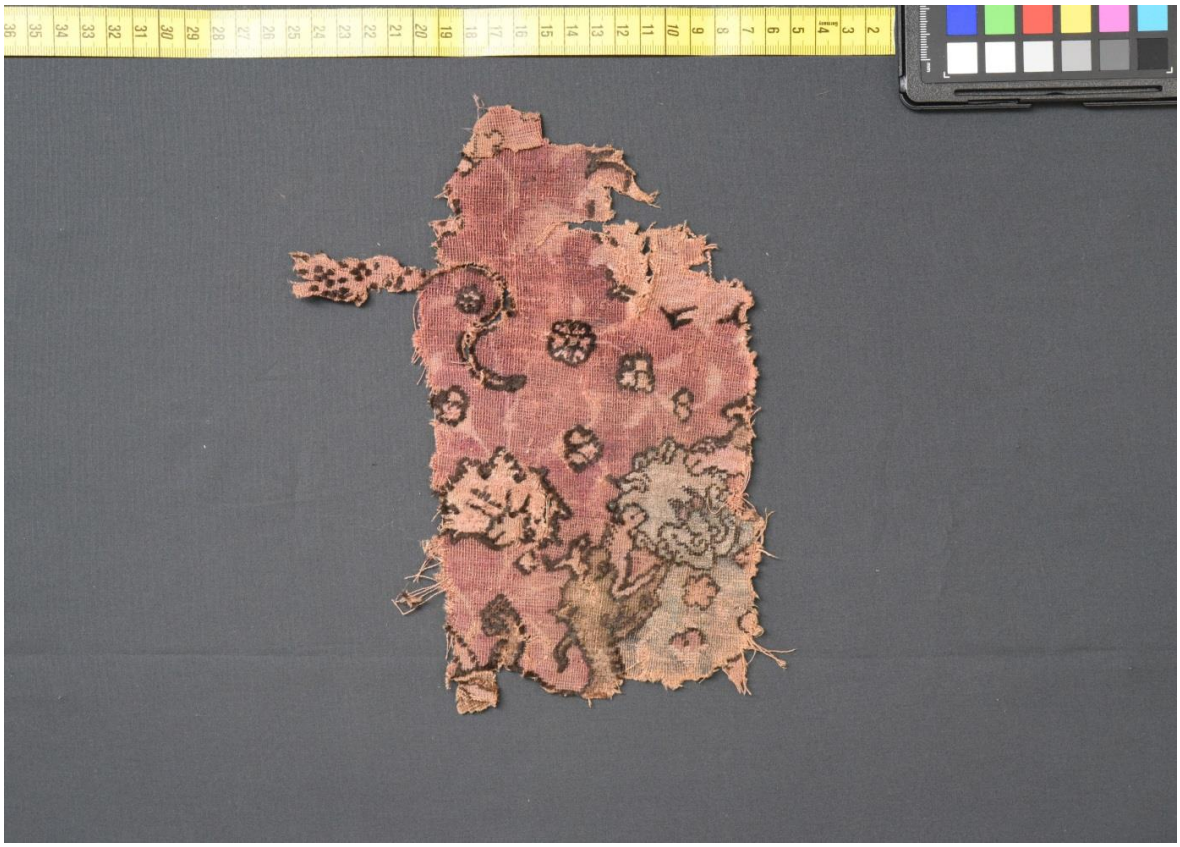


Fragment IX - front (above) and back (below).



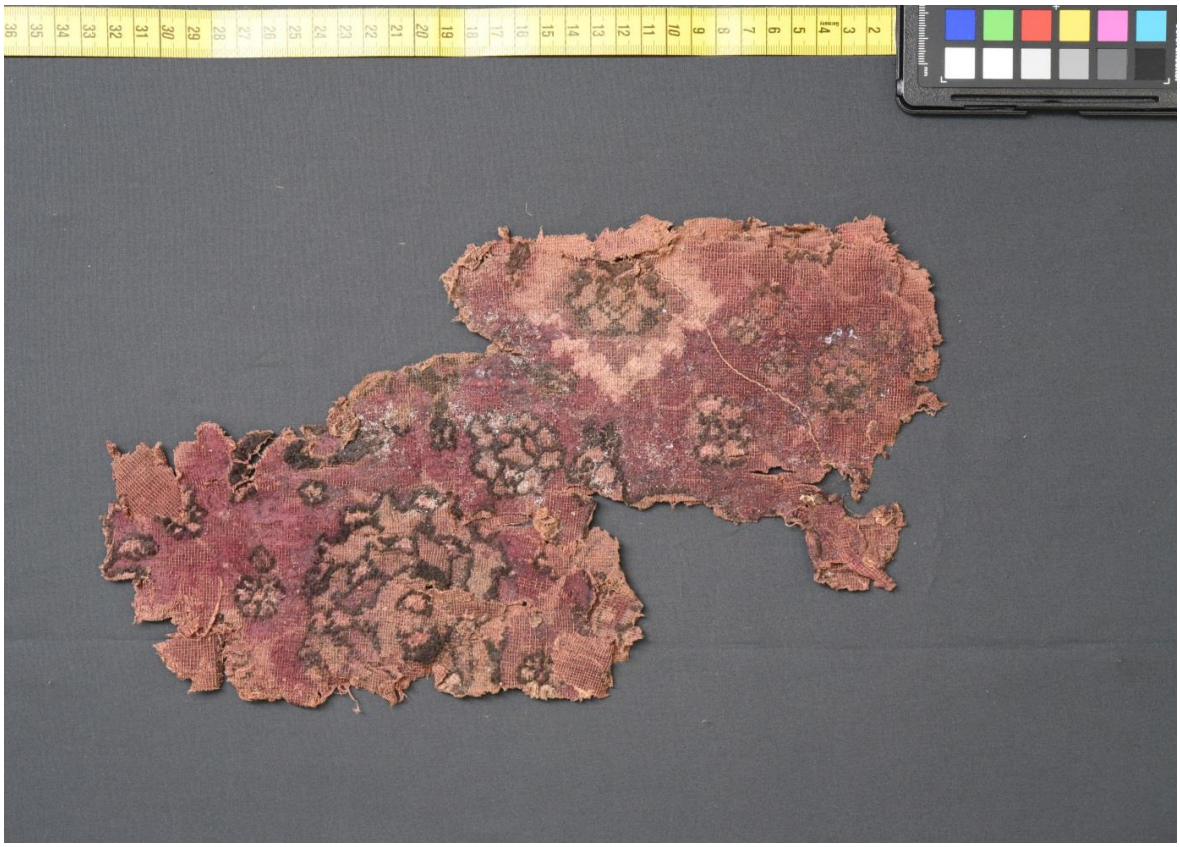


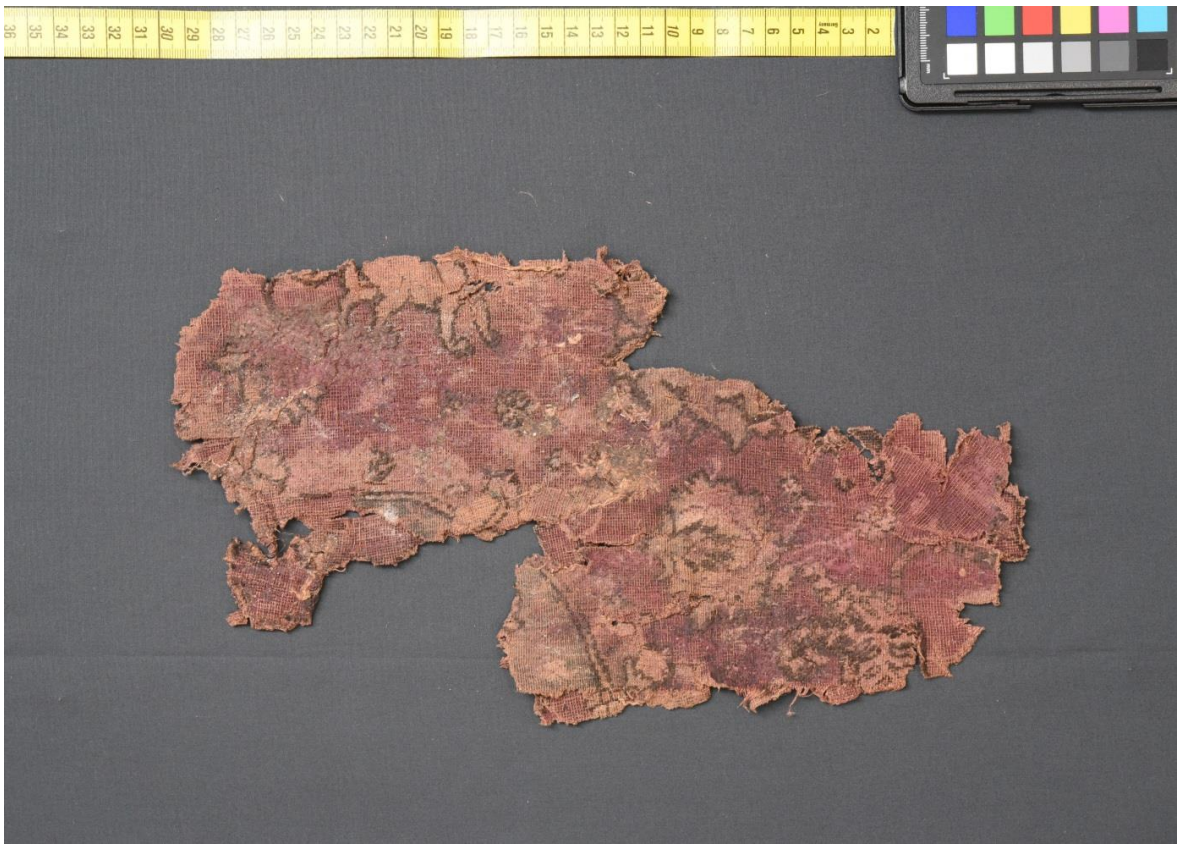
Fragment X - front (above) and back (below).





Fragment XI - front (above) and back (below).





Fragment XII - front (above) and back (below).





Fragment XIII - front (above) and back (below).





Appendix II - Condition Assessment

Fragment I

Dimensions (WxH): 33.8 x 24.4 mm.
Motifs: a lion attacking a bovine creature (cow or bull). Palmettes and flowers.
Description of condition: the fragment has vibrant colours in pale yellow, deep red and deep black. The black pile is in good condition with only slight matting. More severe matting can be seen in the yellow pile of the lion's shoulder, the area of red and yellow pile above the bovine's back leg, and the red pile below its front leg. Overall most of the black pile remains (>75%), around half of the red pile, and only a little (<25%) of the yellow pile. The piece has minor contamination of sand grains, and only small spots with soiling. Some red dye appears to have bled onto the lion's body, creating a light pink stain. In the lower left corner two pieces have been folded double and are matted together. The back appears very clean, with little to no contamination.

Fragment II

Dimensions (WxH): 22.6 x 25.7 mm.
Motifs: jumping antelope. Head of a large cat. Wisps of cloud-bands. Small palmettes and flowers.
Description of condition: the outlines of the figures are a deep black colour. The outlines have almost completely (>90%) retained their pile, whereas in the red and yellow areas the pile is mostly gone (<25%). The loss of pile gives the fragments a faded appearance. Remnants of a pink or orange pile can be seen in a palmette in the lower right corner. There is little to no contamination of sand or soiling. At the upper corners some pieces of material have folded double and are stuck together. The back has no obvious contamination either.

Fragment III

Dimensions (WxH): 27.2 x 16.9 mm.
Motifs: body and wings of bird. Another bird's head. Large palmette and small flowers. Corner of a geometric shape.
Description of condition: the colour of the fragment appears slightly faded. Its main colour is pink, with some additional darker red, dark blue, and the outline of the figures which has faded to a brown colour. Most (>75%) of the pink, red, and brown pile remains, but is very matted, almost as if felted, and is imbedded with grains of sand. The pile in the yellow and blue areas is almost completely gone (<10%). In the lower left corner and at the right edge pieces of material have folded over and are matted together. The back is much cleaner than the front with the exception of the area below the bird's head: the pink wool has a matted appearance and is contaminated with sand.

Fragment IV

Dimensions (WxH): 14.1 x 13.0 mm.
Motifs: body of a lion.
Description of condition: the colours of this fragment have faded. The body of the lion shows traces of pink pile. Most of the black outlines have turned brown, with only a small piece at the lion's mane still retaining colour. Most (>75%) of the red pile of the outlines remains, but the area under the lion's feet, made from the same colour, has lost its pile. The brown pile is somewhat matted together, but shows no contamination. Little to no (<10%) red or yellow pile remains. The back of the fragment shows no contamination.

Fragment V

Dimensions (WxH): 6.9 x 8.8 mm.
Motifs: body of a bird.
Description of condition: most of the outlines have faded to a brown colour, with only part of the wing remaining black. The pile of the outline is mostly (>75%) retained. The blue and red pile has disappeared completely. One of the wings retains its pink pile. Overall the pile has very little matting. There is some minor contamination with grains of sand.

Fragment VI

Dimensions (WxH): 6.6 x 13.8 mm.
Motifs: small palmette and flowers
Description of condition: the colours are very faded with the exception of the black outlines. Most (>75%) of the black pile remains. Little (<25%) of both the yellow and the red pile remains. Overall the pile is very matted and imbedded with contamination such as sand and a small rock, and thick thread (most likely these belong to the fringe). The back also has some matted and contaminated areas.

Fragment VII

Dimensions (WxH): 22.2 x 9.9 mm.
Motifs: head of a bird. Large palmettes. Edge of a geometric shape.
Description of condition: colours of this fragment appear faded. Most (>75%) of both the pink and black pile remains. The blue and yellow pile are mostly gone. Inside the palmettes about half of the dark red pile is retained. Overall the pile is very matted, almost felted in appearance, and contaminated with grains of sand. Long thick threads are stuck to the surface (again, most likely part of the fringe). At the right edge a piece of material if folded double. The back is mostly clean, with only the bottom edge showing minor contamination with sand. The appearance of the wool of the back is matted.

Fragment VIII

Dimensions (WxH): 33.2 x 21.9 mm.

Motifs: band of stems and flowers. Cloud-bands. Large palmettes. Edge of a geometric shape (quatrefoil, fig. II.1).

Description of condition: the colours are faded but red, orange, pink, yellow and blue can still be distinguished. The area of the cloud-bands has almost no (<10%) pile remaining. In the band of flowers most of the pile of the brown outlines remains (>75%) whereas only a little (25-50%) of the yellow and pink pile remains. The pink and yellow pile of this area is much more matted than the brown pile. The blue pile is completely gone. Only a little (25-50%) of the dark red pile inside the geometric shape remains. Overall the piece appears very clean, with only a single spot of black soiling on the back.

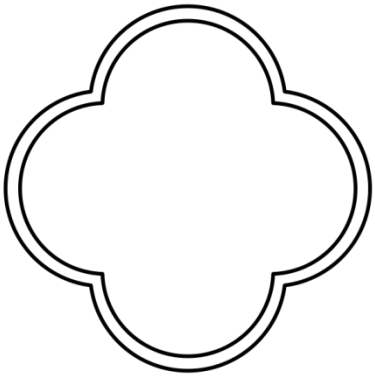


Fig. II.1 - Quatrefoil: shape created by four overlapping circles.
(Source: <https://commons.wikimedia.org/wiki/File:Quatrefoil-Architectural.svg> 24 May 2017.)

Fragment IX

Dimensions (WxH): 36.8 x 20.7 mm.

Motifs: band of stems and flowers. Cloud-bands. Large palmettes. Edge of two geometric shapes (quatrefoil).

Description of condition: similar to fragment VIII in terms of motifs and colours. Shape-wise the pieces are mirrored. However, much more (>75%) of the pile of fragment IX remains, and the overall colours are more defined. The pile is very matted, and contaminated with many imbedded grains of sand and a small rock. Again the pile of the outline is less matted than the surrounding pink and yellow pile. The blue pile is completely gone. The back has a little matting, some contamination with sand, and a spot of grey soiling at the top edge.

Fragment X

Dimensions (WxH): 16.5 x 24.2 mm.

Motifs: two dragons with beak. Dog or lion-like head. Tail and behind of a spotted cat. Small palmettes and flowers.

Description of condition: the colours are slightly faded. Fragment X is the only to show a green colour in the head of the dragon. Of the pile of the dark red background only a small portion (<10%) remains. About half of the pink pile inside the flowers remains. A little (25-50%) of the green pile remains. In the yellow and blue areas all of the pile has disappeared. The fragment is clean, with no contamination except for grains of sand in the blue area. The back is equally clean. At both the top and bottom edge pieces of material are folded over.

Fragment XI

Dimensions (WxH): 34.1 x 19.5 mm.

Motifs: (front) large palmettes, small flowers. (back) Body of a lion. Back half of a tiger. Large palmettes. Edge of a geometric shape.

Description of condition: fragments consists of two pieces matted together back-to-back. Colours are very saturated, much darker than other fragments. On the front, most (>75%) of the dark red pile remains. This pile is severely matted, almost felted in appearance, and contaminated with many grains of sand. Small pieces of tissue paper are stuck to the surface (an attempt was made by the author to remove these pieces using tweezers and a scalpel, but not all could be removed without damaging the underlying pile.). Some of the black outline has faded to a dark brown. Much (>75%) of the black pile remains, and it is less matted than the red areas. Small spots of pink pile remain inside the palmettes. The back has the same matted appearance; in these areas it is difficult to distinguish individual wool threads. There is less contamination with sand than on the front side, but there is a small rock imbedded in the pile. There are small spots of grey soiling. Most (>75%) of the black pile remains, but all blue and yellow pile has disappeared.

Fragment XII

Dimensions (WxH): 14.6 x 16.8 mm

Motifs: geometric shape (trefoil and ogee arch, fig. II.2). Cloud-bands. Palmettes.

Description of condition: the colours of this fragment are very faded. Black outline has faded to a medium brown. Very little (<10%) of the overall pile remains. A small amount of pink and pale yellow pile can be seen in the palmettes. The front is mostly clean, but some contamination with grains of sand can be found in the folds. The back has much sand all-over the surface.

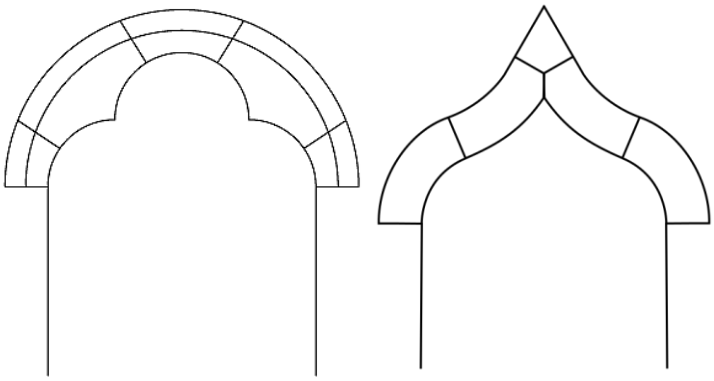


Fig. II.2 - Trefoil arch (left) and Ogee arch (right). The geometric shapes of fragment XII and XIII are created by overlapping both arches.
(Source: <https://commons.wikimedia.org/wiki/File:Trepassb%C3% A5ge.png> and <https://commons.wikimedia.org/wiki/File:Ogee-shaped_arch.svg> 24 May 2017.)

Fragment XIII

Dimensions (WxH): 42.6 x 25.2 mm.

Motifs: band of flowers. Cloud-bands. Geometric shape (fig. 2).

Description of condition: the colours of this fragment are very faded. On the bottom are the remnants of a fringe; its threads are still flexible and soft. Almost no pile remains on the fragment except for the top right corner, which has a small amount (<10%) of pink, yellow and red pile. This pile is slightly matted and has some contamination with grains of sand. The rest of the surface is very clean. In the top left area are some very small black stains. Bright orange stains (perhaps the deterioration product of a metal) are seen on the edge of the fringe and the bottom right area. In the middle of the top edge is a spot with material which appears to have been woven in rather than knotted (fig. II.3). One possible explanation is that this is an old repair. The back also has very little contamination, and bright orange stains. Several pieces of material along the top edge have been folded double.



Fig. II. 3 - Detail of fragment XIII, showing in light grey the woven-in material. Photo by author.

Appendix III - Hirox Images

The following images were created on 23 May 2017 using a Hirox KH7700 digital microscope, operated by Kate van Lookeren-Campagne at the Ateliergebouw, Amsterdam. The arrows in each picture indicate the direction of the warp threads.



Fig. III.1 - detail of fragment I, black and red pile.

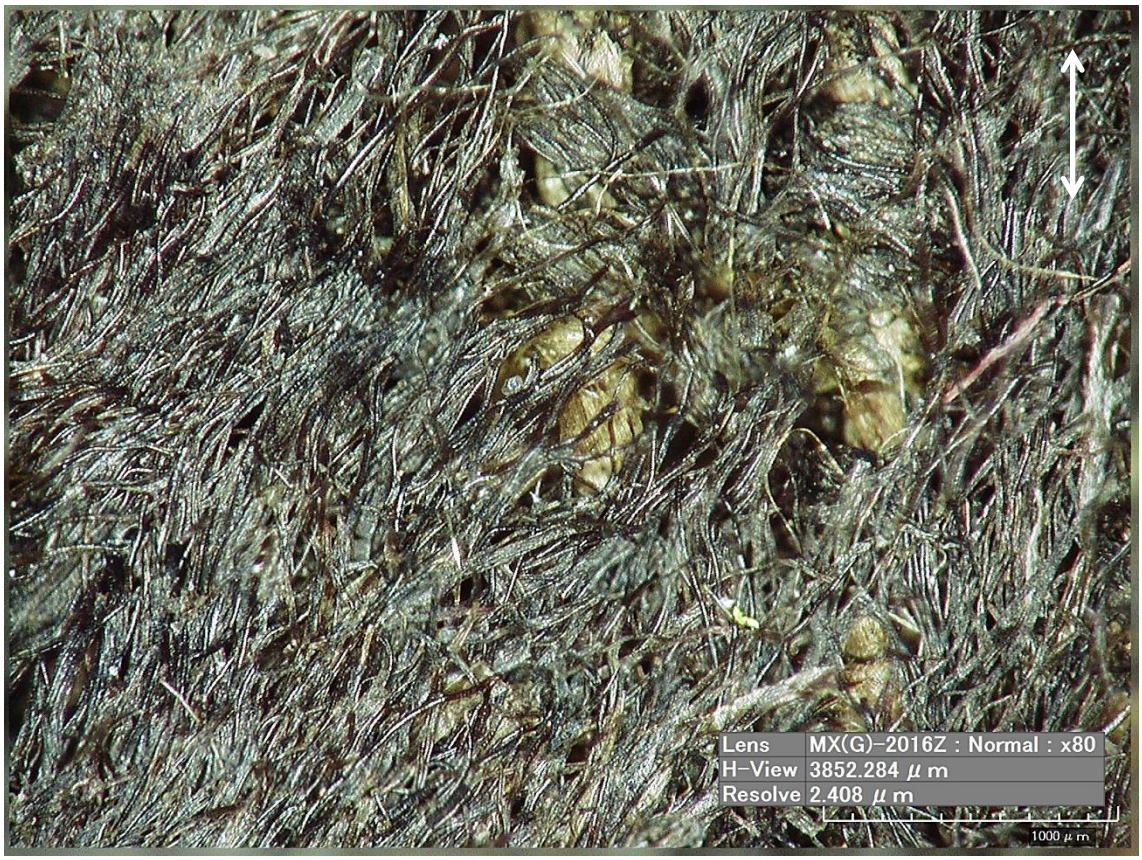


Fig. III.2 - detail of fragment I, black pile.



Fig. III.3 - detail of fragment I, red pile.

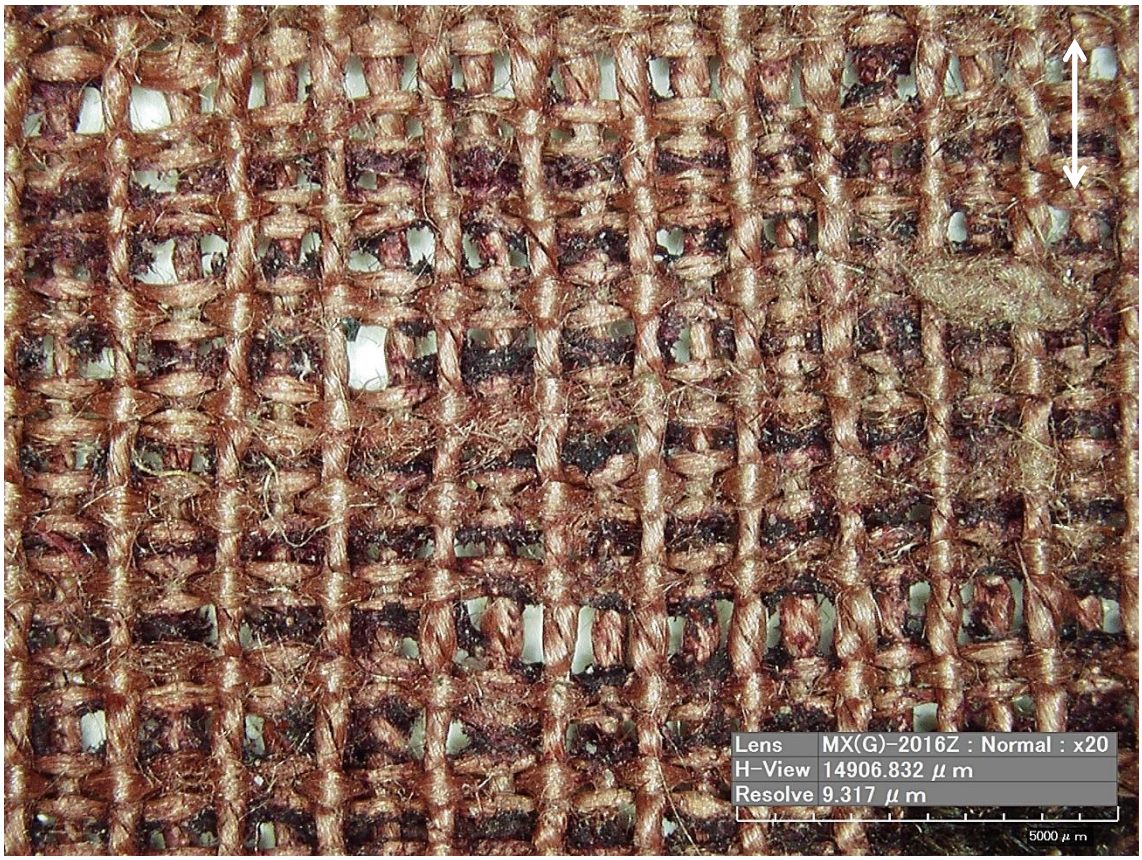


Fig. III.4 - detail of fragment I, structure of the ground weave.

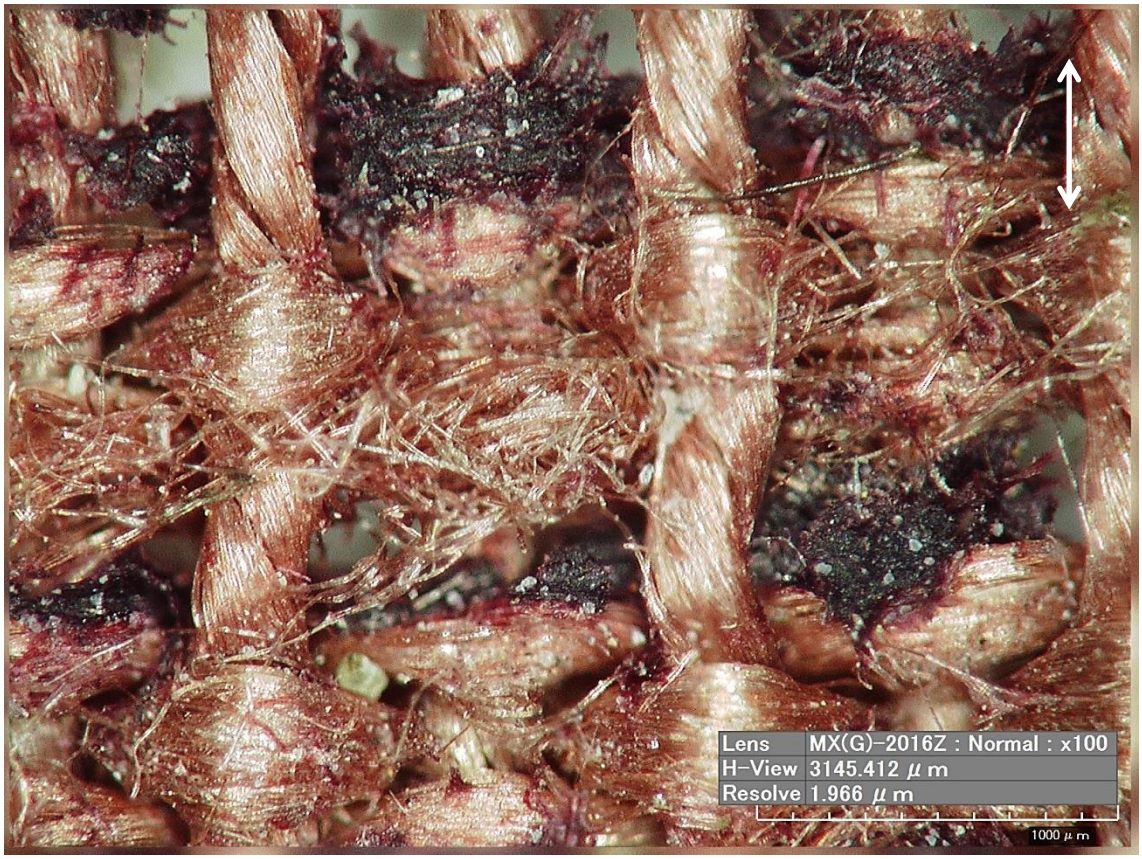


Fig. III.5 - detail of fragment II, detail of the ground weave.



Fig. III.6 - detail of fragment X, remains of metallic thread.



Fig. III.7 - detail of fragment XI, contamination of the pile.

Appendix IV - BZN8 Mittens

The BZN8 shipwreck is located northeast of the BZN17. The ship is assumed to have been built between 1643 and 1650, and sank somewhere in the third quarter of the 17th century. Two expeditions were organised by the RCE to explore the ship, in 1998 and in 2002. The second yielded many finds coming from the rear of the ship: the personal belongings of the crew. Among these were a leather mitten with a woollen lining, and a woollen mitten.[111] The finds were registered as [MA]BZN8-219 and [MA]BZN8-220 respectively, and are kept in storage in the maritime depot of the RCE in Lelystad.

Object Records

Objectbeschrijving	Leren handschoen of want, met wollen gehaakte voering, voor 4 vingers en een duim. De 7 onderdelen van de want zijn: 1) bovendeel van linkerhand, 2 x een lijn versieringspatroon, met vast duimstuk, en op rugzijde een ovaal reparatiegat. 2) los driezijdig duimstok, hoort bij vaste duimstuk van 1) 3) los vijfzijdig stuk leer met naaigaten rondom, hoort bij vaste duimstuk van 1) 4) stripje leer met naaigaten in 2 delen 5) los vetertje 6) reparatie ovaal 7) wollen gehaakte binnenvoering
Objectnummer	[MA]BZN8-219
Objectnaam	**handschoen, want**
Materiaal	**Leer, Wol**
Scheepswrak	Burgzand Noord 8 / BZN8 / Lelie 1
Provincie	Noord-Holland
Plaats	Waddenzee
Naam schip	onbekend
Type schip	koopvaardijschip
Datering / Vergaan	derde kwart 17de eeuw
Tags	*Er zijn nog geen tags toegevoegd*



Objectbeschrijving	1 wollen handschoen of want (24 x 12 cm), voor vier vingers en duim van rechterhand, gebreide wol, met spoortje teer.
Objectnummer	[MA]BZN8-220
Objectnaam	**handschoen, want**
Materiaal	**Textiel, Wol**
Scheepswrak	Burgzand Noord 8 / BZN8 / Lelie 1
Provincie	Noord-Holland
Plaats	Waddenzee
Naam schip	onbekend
Type schip	koopvaardijschip
Datering / Vergaan	derde kwart 17de eeuw
Tags	*Er zijn nog geen tags toegevoegd*



Taken from the online database of the RCE: <http://cultureelerfgoed.adlibsoft.com/search.aspx>.

Sampling

Four samples were taken on 15 May 2017, two from each object. From each object one sample was taken from the middle of the object, and one from the edge. From [MA]BZN8-219 sample L.1 and L.2 were taken. From [MA]BZN8-220 sample M.1 and M.2.

[111] Vos, Arent. D. *Onderwaterarcheologie op de Rede van Texel. Waardestellende onderzoeken in de westelijke Waddenzee (Burgzand*). Amersfoort: Rijksdienst voor het Cultureel Erfgoed, 2012, p. 193-209.

Mitten lining BZN8-219



Mitten BZN8-220



Photographs by author.

SEM Images

Using the samples taken above, the following SEM images were created on 12 June 2017 using a Nova NanoSEM 450 by FEI, with the composition established using EDX by ThermoScientific and NSS software. The devices were operated by Ineke Joosten of the RCE at the Ateliergebouw, Amsterdam.

Using EDX the material in fig. 4 was found to contain iron and sulphur, and is probably pyrite. The material of the 'crust' on the fibres of sample M.2 was found to contain iron, sodium, aluminium and silicon, elements commonly found in sediment or soil.



Fig. IV.1 - Sample L.1, wool fibres surrounded by severe contamination.



Fig. IV.2 - Sample L.1, mechanical damage of a wool fibre.

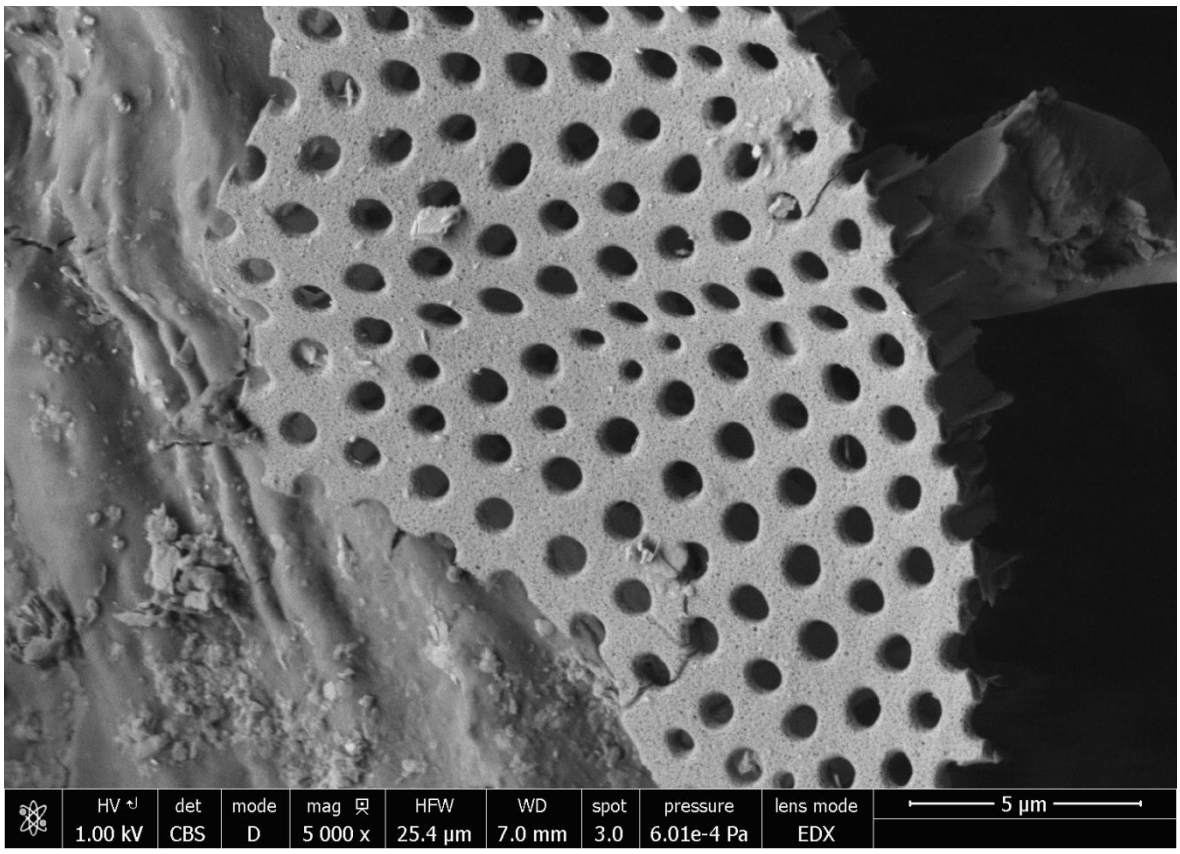


Fig. IV.3 - Sample L.1, the remains of a diatom.

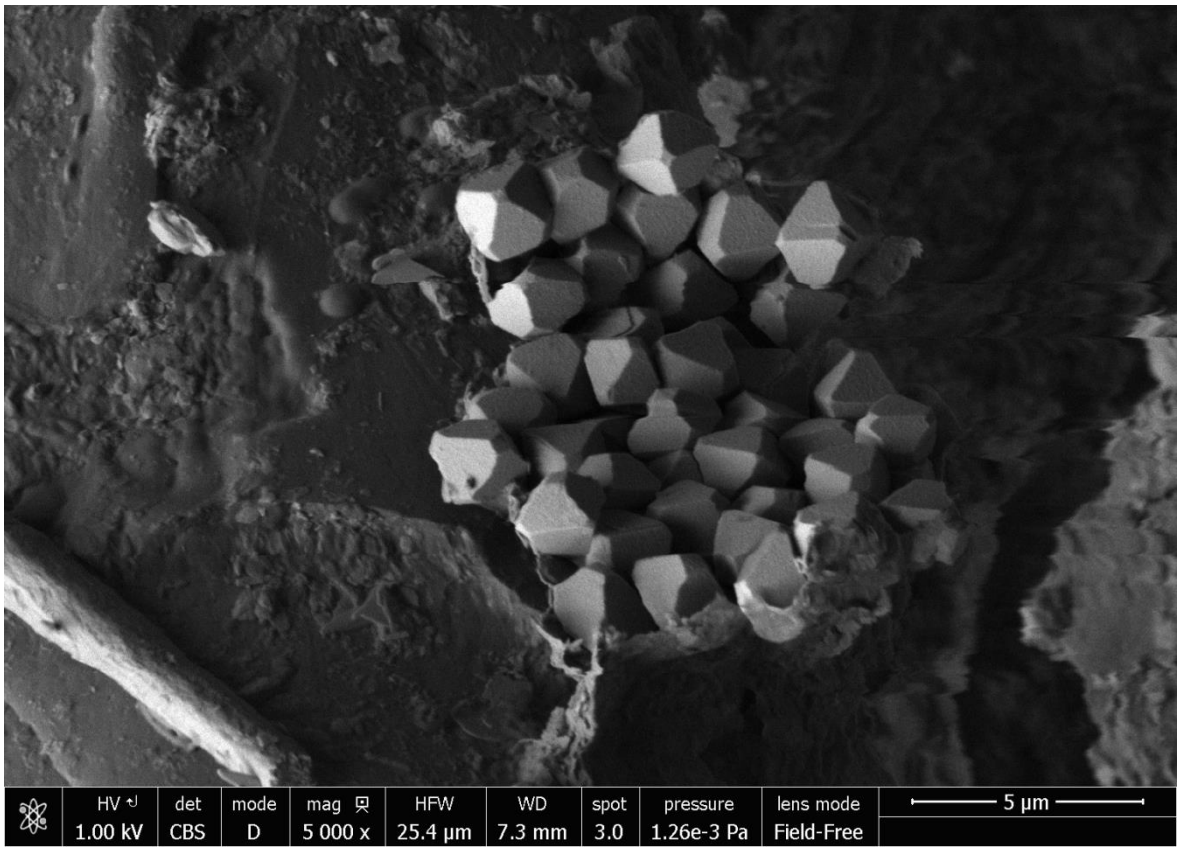


Fig. IV.4 - Sample L.1, a cluster of pyrite.

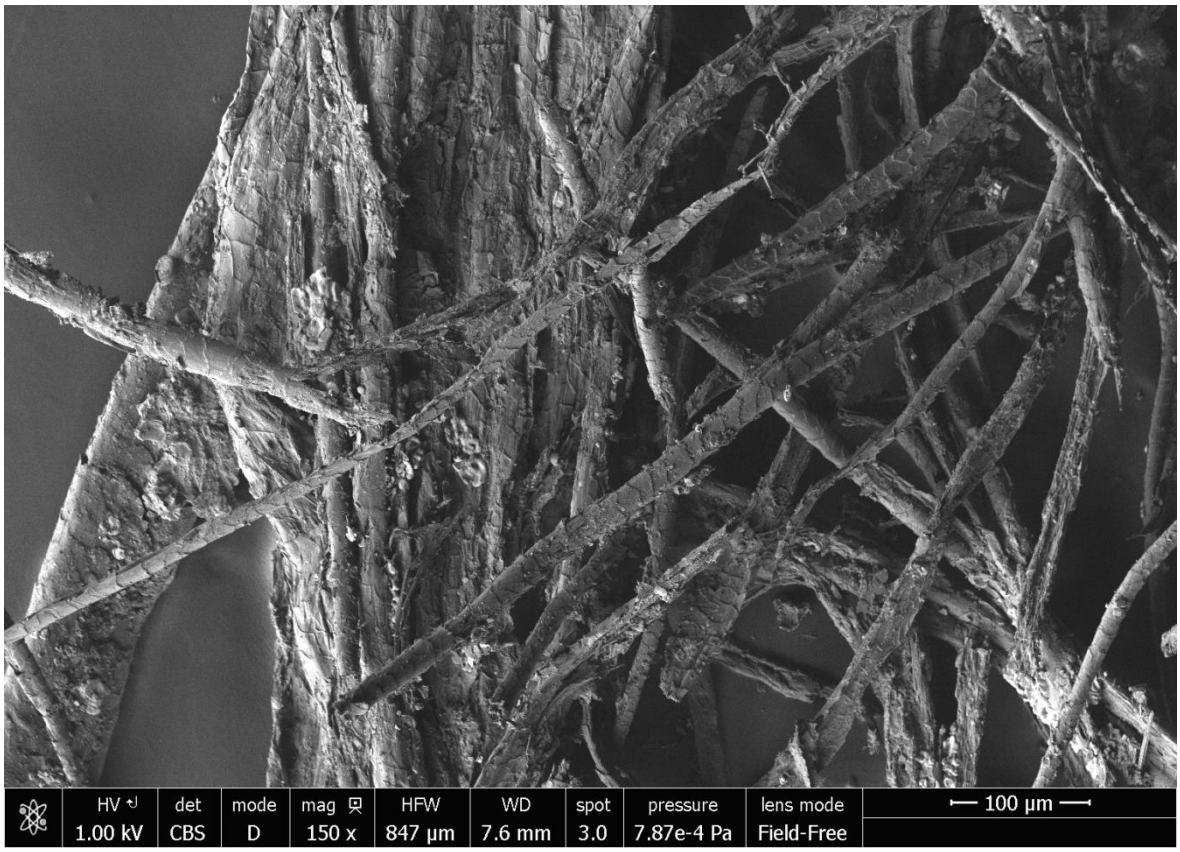


Fig. IV.5 - Sample L.2, wool fibres and moderate contamination.

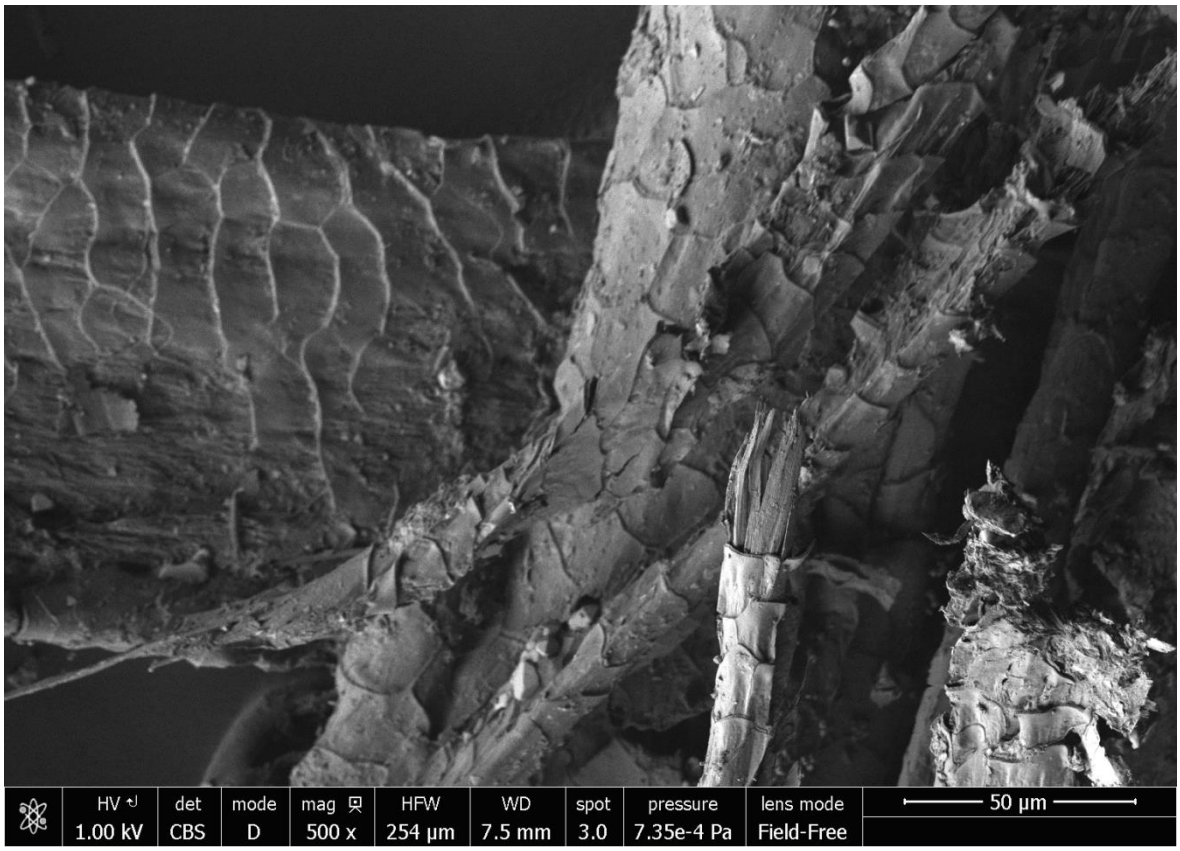


Fig. IV.6 - Sample L.2, detail of the scales.

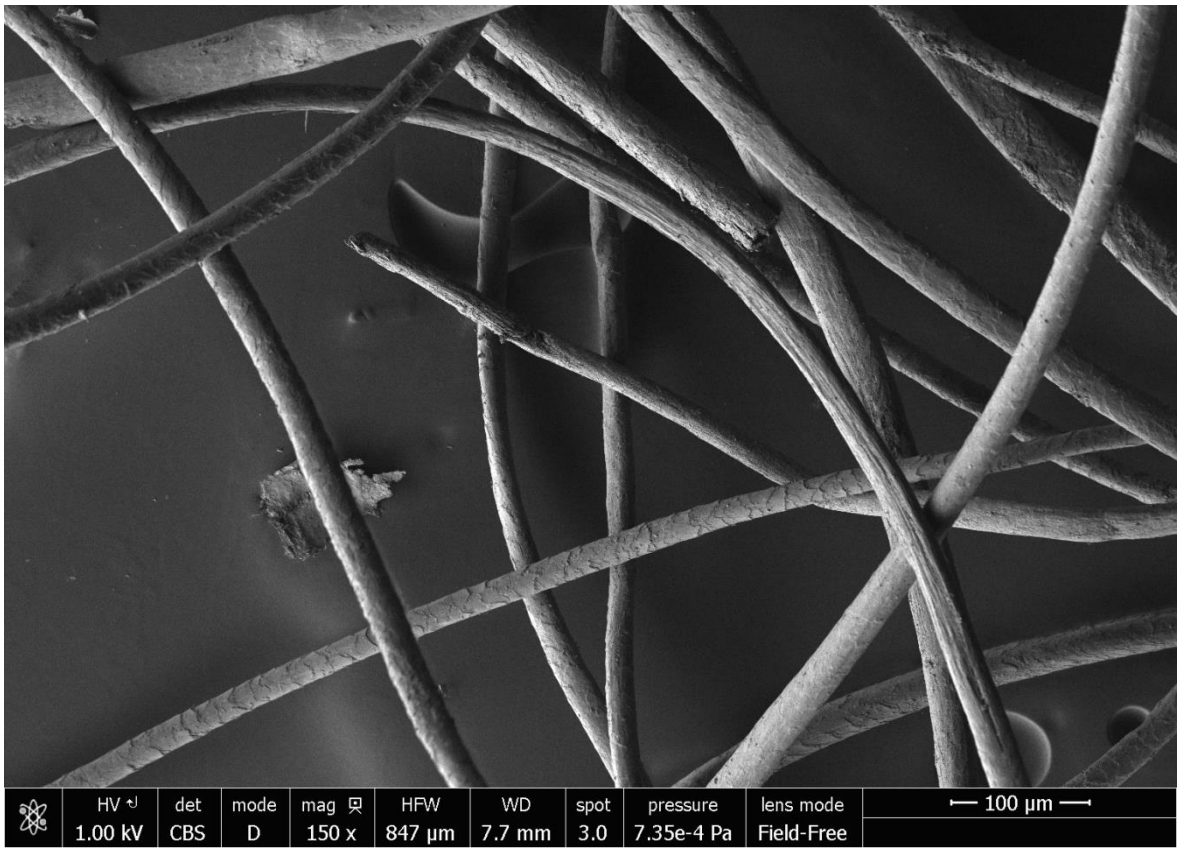


Fig. IV.7 - Sample M.1, wool fibres without any contamination.

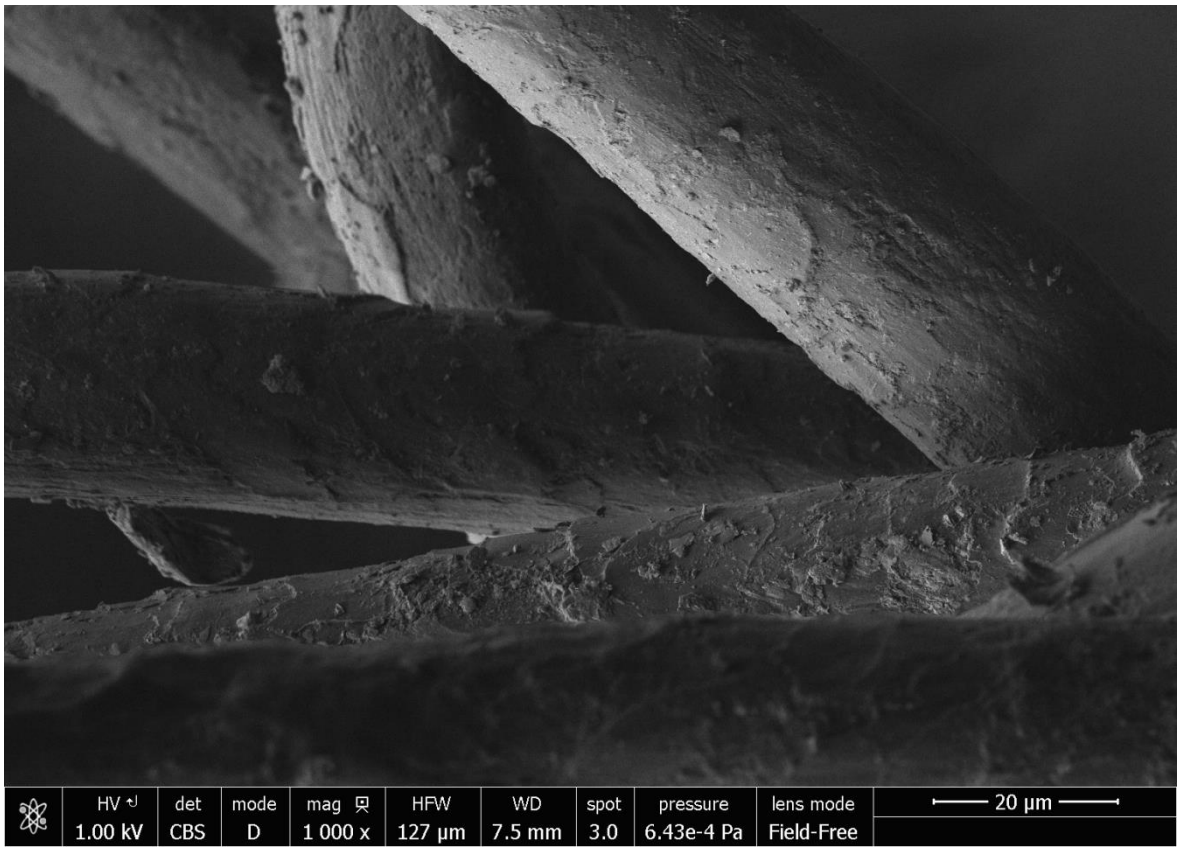


Fig. IV.8 - Sample M.1, detail of the smooth surface of the fibres.

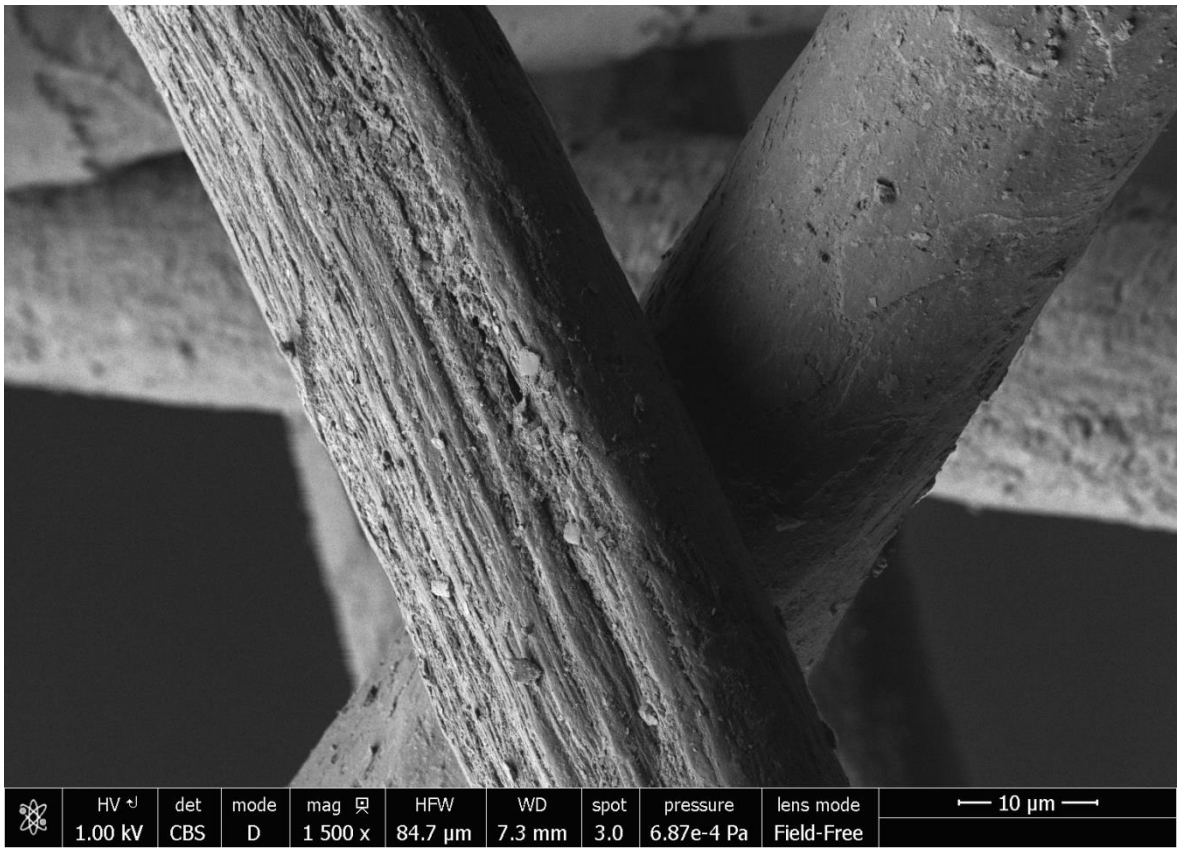


Fig. IV.9 - Sample M.1, detail of the exposed fibril core.

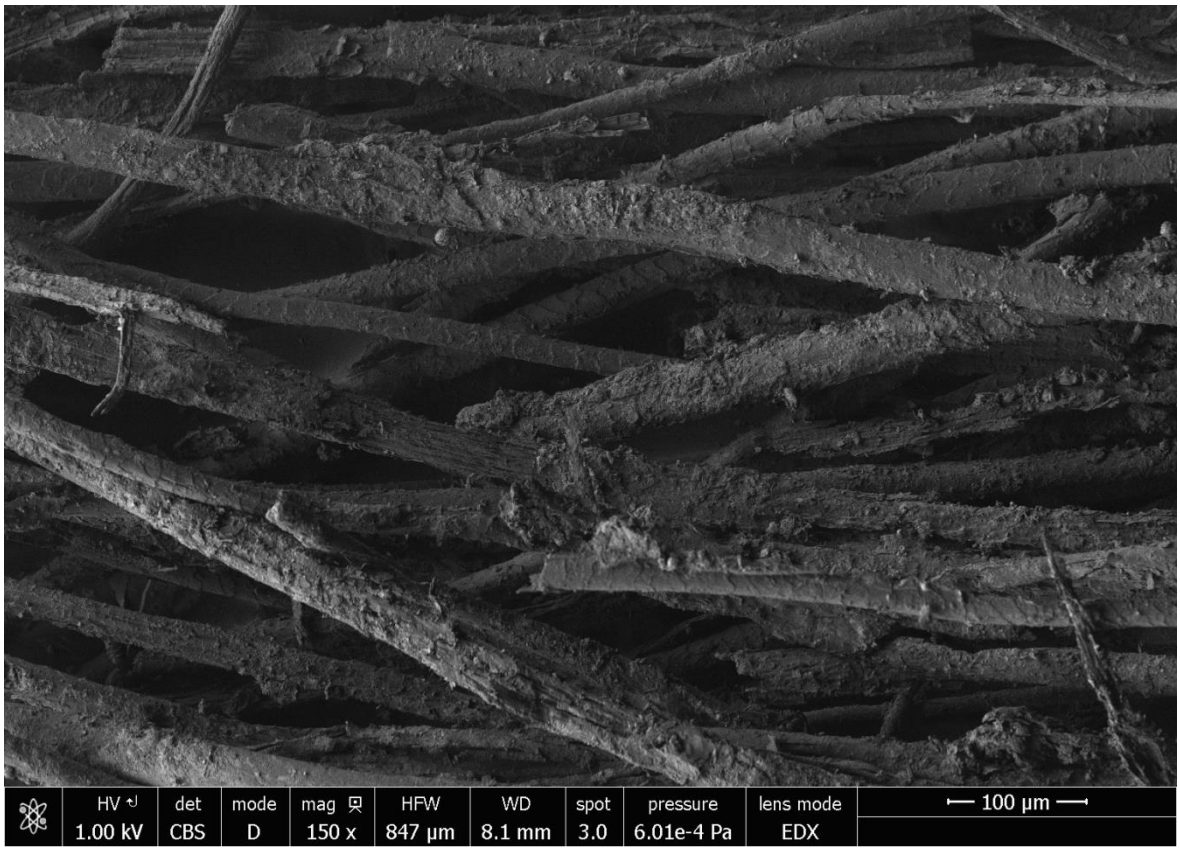


Fig. IV.10 - Sample M.2.

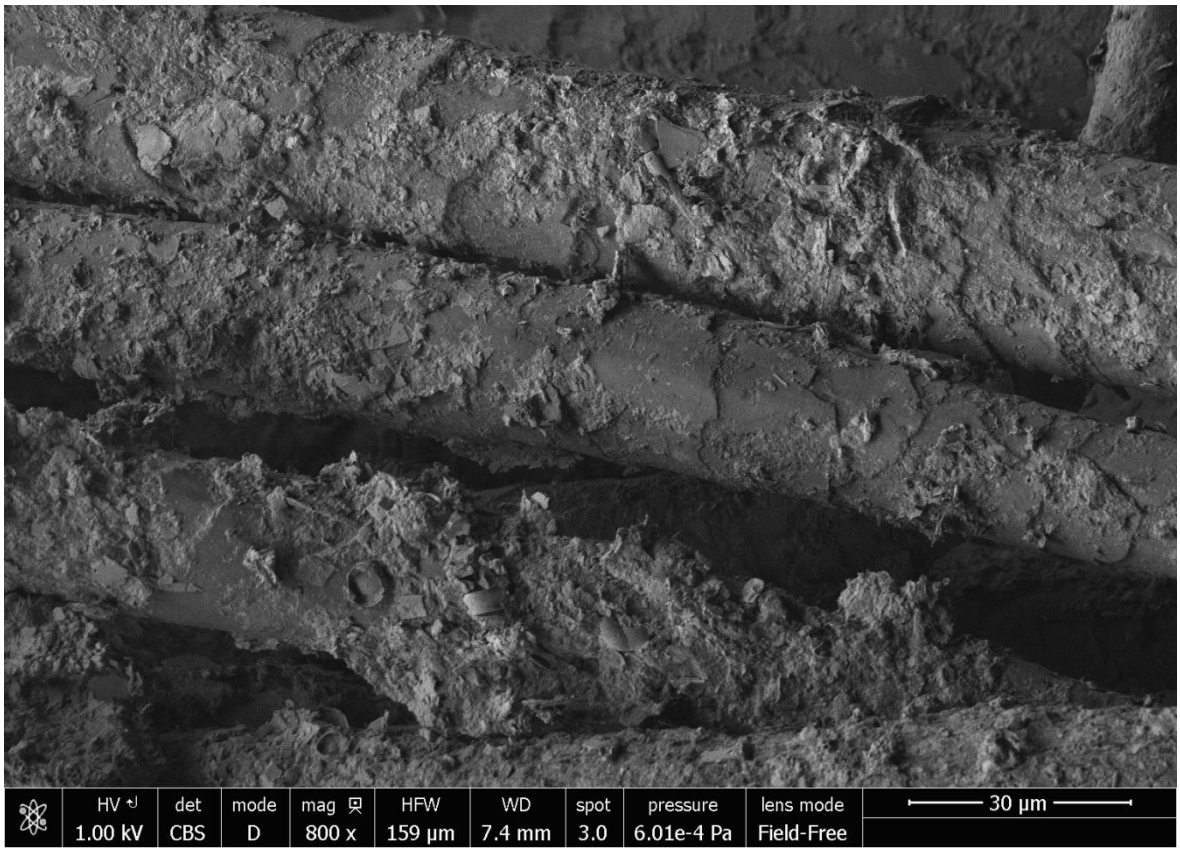
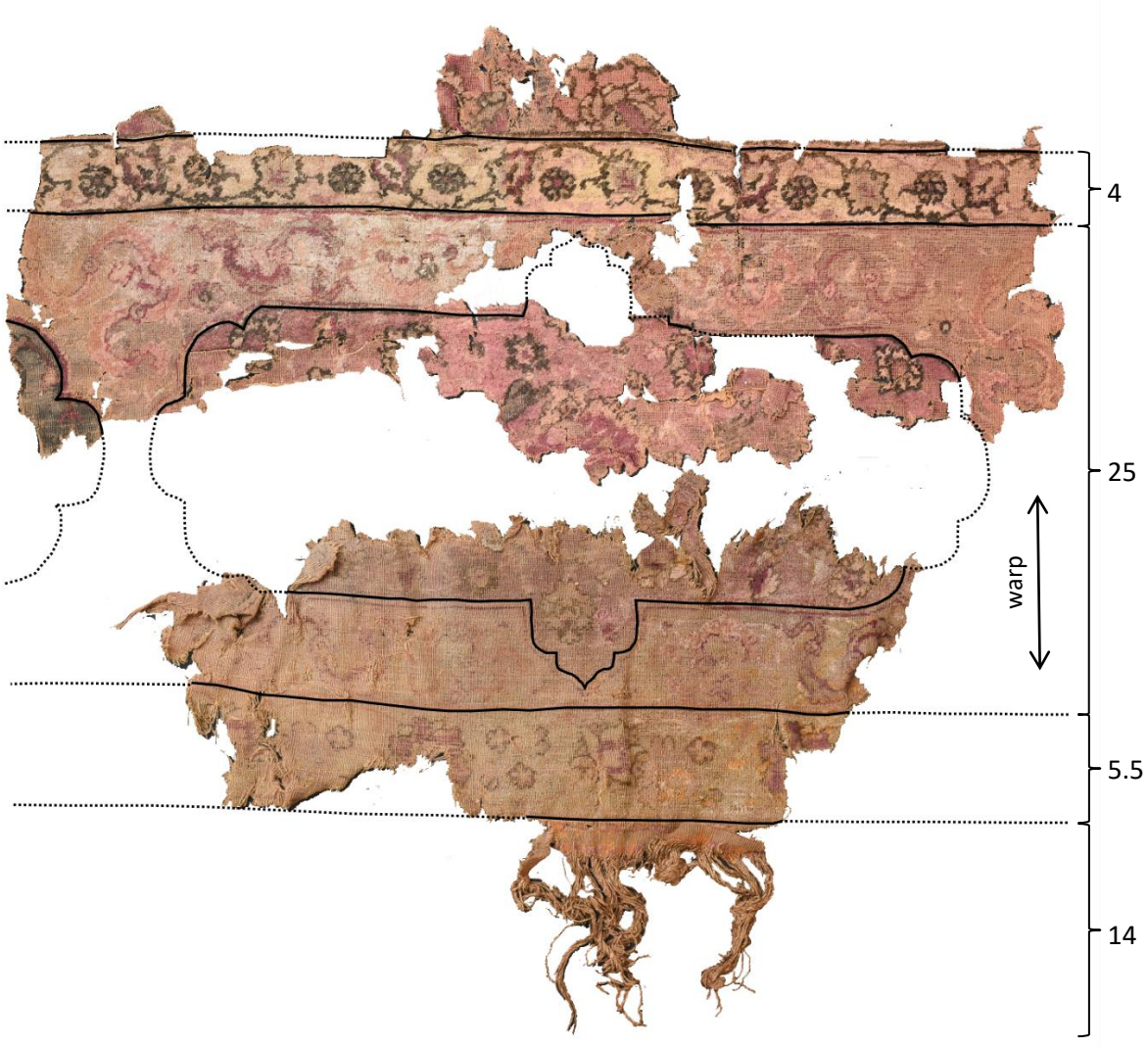


Fig. IV.11 - Sample M.2.

Appendix V - Border Design Reconstruction

The image below was created in Adobe Photoshop CC 2015 using images of fragments VII, VIII, IX and XIII. Shown on the right are the heights of the various elements in centimetres. The reconstruction is based on matching elements, such as the borders of flowers or geometric shapes, in the fragments. It is not based on the overall shape of the fragments, one image was flipped, and the fragments overlap. It is important to emphasise the fragments do not belong together in this manner. This reconstruction is merely an attempt at recreating an impression of the design of the original border.



Appendix VI - Cultural Context: the Safavids

Founded in 1501, the Safavid dynasty brought a long period of stability and growth to the Persian Empire, which lasted until 1736 (fig. VI.1). Before the rise of the first Safavid Shah, Ismail I (1487-1524), the death of the previous ruler had left Persia a divided land with local clans warring over territory. Over a span of ten years Ismail I managed to conquer and unite all of Persia, and install himself as an absolute monarch. It was under his rule that Shia Islam was declared the official state religion, although the actual process of conversion of the whole of the Sunni population would take several more generations. Safavid Persia would become a feudal theocracy, its new religion cementing internal cohesion and providing distinction from the neighbouring and rival Ottoman Empire.[112] The true heyday of the dynasty was reached under the rule of Shah Abbas I (1571-1629), who ascended in 1588. He moved the capital city to Isfahan in 1598 and reformed the administrative system to create a strong, centralised government.[113] Industry and trade were reinvigorated under his rule, elevating the standard of living for the general

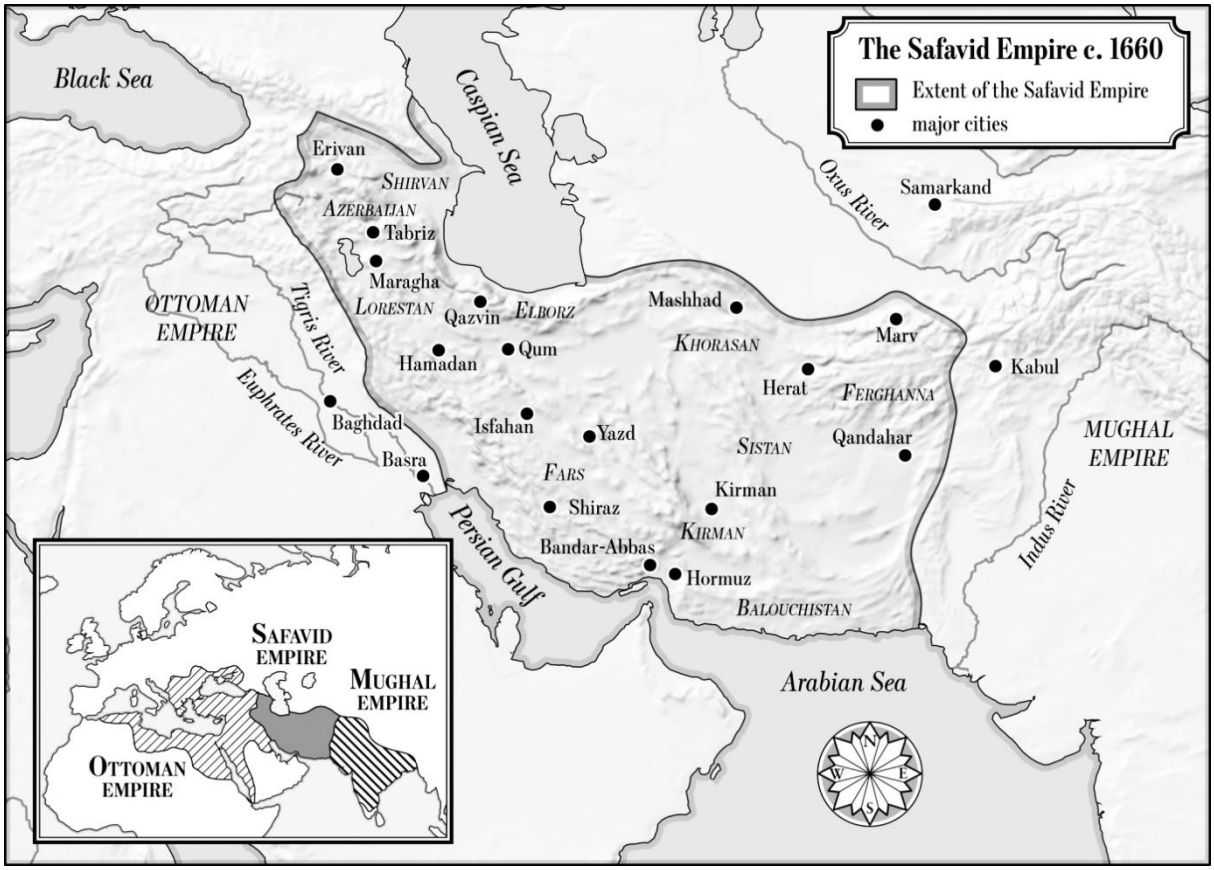


Fig. VI.1 - The Persian Empire under the Safavid dynasty. Blake, Stephen P. "Safavid, Mughal, and Ottoman Empires." Time in Early Modern Islam: Calendar, Ceremony, and Chronology in the Safavid, Mughal and Ottoman Empires, Cambridge University Press, Cambridge, 2013. (Source: <https://www.cambridge.org/core/books/time-in-early-modern-islam/safavid-mughal-and-ottoman-empires> 20 April 2017.)

[112] Roemer 1986: 336.

[113] This new system was greatly effective, and continued to exist for at least another 100 years after his death, in spite of the incompetence of his successors. Savory 1986: 366.

population. Contacts with other major powers intensified, leading to a fruitful trade with the Western world, and the presence and influence of European merchants, artists and monks within the Persian Empire.[114] It was in this favourable climate that the arts of the Persian Empire flourished. Shah Abbas I's successors built off these foundations, but none were able to match his achievements. The decline of the Safavid Dynasty started around the turn of the 18th century. Internal quarrels, both of religious and ethnic nature, weakened national cohesion, giving rise to separatist groups. During these years the Afghan Ghalzai tribe managed to seize power, marched all the way to Isfahan, and in 1722 after a short siege claimed the city, the throne, and the whole of the Persian Empire for themselves, ending Safavid rule.[115]

Contact with the Western World

There are two distinct phases in the contact and trade between Persia and Europe. At the turn of the 16th century it was Portugal who first established a long naval route leading past Persia and on to India and beyond. In 1507 the Portuguese fleet captured the island of Hurmuz of the coast of Persia. A treaty was made with Shah Ismail I that in return for their help to recapture the Bahrain islands for Persia, Portugal was allowed to keep Hurmuz as a vassal state. The island was to remain a Portuguese naval base and trade outpost for over a century. This monopoly over European-Persian trade meant that the first Persian goods, including carpets, entered the European market through Portugal.[116]

The first diplomatic representation of Europe in Persia was also of Portuguese origin: the tolerant policies of Shah Abbas I allowed Augustinian monks to establish a convent in Isfahan in 1602.[117] In return, the shah sent envoys to Europe with the intention of bettering the silk trade. Silk was Persia's main export commodity and a key factor in its prosperity. Until then all export had traversed through Turkey which had a negative impact on trade during times of unrest between Persians and Ottomans.[118] The establishment of a route independent from Ottoman influence was therefore of interest to both Persians and Europeans. Attempts were made by the English to create an alternative route over land through Russia as a means to export English cloth to Persia, and in turn import silk. The journey was rather difficult and slow compared to travel by ship, and never gained much popularity.[119]

[114] Roemer 1986: 269-71.

[115] The rule under the Ghalzai tribe was short-lived, ending due to internal strife. From 1730 to 1736 several Safavid pretenders made claim to the throne. None were able to fully grasp power, and the throne was eventually seized by the Afsharid Dynasty. Roemer 1986: 313-25.

[116] Persian carpets were a sought-after luxury for the elite, and appear for the first time in Portuguese painting in the middle of the 16th century. Eastern carpets had been depicted in Europe before, such as the Turkish carpets seen in Italian painting. Hallett 2007b: 79.

[117] Lockhart 1986: 378, 380-89.

[118] Ferrier 1986: 430-431, 435.

[119] The journey took the English around the north of Norway to the White Sea, then by land until they reached the Volga and down to the Caspian Sea. The final stretch was again on foot. The roads travelled were much less safe than the established routes leading east to west which had towns and caravanserais (roadside inns along the trade routes where caravans could rest) at regular intervals and were kept in

It was not until the 17th century that the English EIC actively sought out trade with Persia. In 1614 they helped Abbas I recover Hurmuz from Portugal, signalling the end of Portuguese dominance in the region.[120] In 1616 special permissions and privileges were given to the English to facilitate trade. These same negotiations were made with the VOC in 1624. From that moment on Persian floral cloud-band carpets start appearing on Dutch paintings, implying an upsurge in the import of this type of object.[121] In 1617 the EIC opened silk factories in Isfahan and Shiraz, producing goods for the English market. The Dutch followed suit. The English and Dutch rivalled over trade with Persia, both being encouraged in their endeavours by the Shah who profited from their import of silks. The availability of ready money eventually led to the Dutch gaining the overhand, becoming the leading importer of spices. This dominance was further established by the outbreak of first Anglo-Dutch War in 1652, after which the EIC was deprived of much of it power, leaving the market free for the Dutch for the remainder of the 17th century.[122]

Reference:

Ferrier, Ronald. "Trade from the Mid-14th Century to the End of the Safavid Period." Peter Jackson and Laurence Lockhart eds. *The Cambridge History of Iran*. *Vol. 6, Timurid and Safavod periods*. Cambridge: Cambridge University Press, 1986. 412-90.

Hallett, Jessica. "Enchanting Gardens." *The Oriental carpet in Portugal: Carpets and paintings, 15th-18th centuries*, Eds. Teresa Pereira and Jessica Hallett. Lisbon: Ministerio da Cultura, 2007. 79-80.

Lockhart, Laurence. "European Contacts with Persia 1350-1736." Peter Jackson and Laurence Lockhart eds. *The Cambridge History of Iran*. *Vol. 6, Timurid and Safavod periods*. Cambridge: Cambridge University Press, 1986. 373-410.

Roemer, Hans R. "The Safavid Period." Peter Jackson and Laurence Lockhart eds. *The Cambridge History of Iran*. *Vol. 6, Timurid and Safavod periods*. Cambridge: Cambridge University Press, 1986. 189-350.

Savory, Roger M. "The Safavid Administrative System." Peter Jackson and Laurence Lockhart eds. *The Cambridge History of Iran*. *Vol. 6, Timurid and Safavod periods*. Cambridge: Cambridge University Press, 1986. 351-72.

Ydema, Onno. *Carpets and Their Datings in Netherlandish Paintings 1540-1700*. Zutphen: Walburg Pers, 1991.

good condition. In contrast, pirate ships sailed the Volga, and bandit groups roamed all over the Caucasus. The independence from the Ottomans did in the end not outweigh the risks associated with the journey. Lockhart 1986: 383.

[120] Lockhart 1986: 393-92.

[121] Eastern carpets had been painted by Dutch artists previously, but they were generally imported from countries closer by, such as Turkey and Egypt. Ydema 1991: 60.

[122] Ferrier 1986: 446-47, 459-63