haute école neuchâtel berne jura

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A study of mineralised organic remains on metal objects from Feldkirchen (4th century AC) and their impact on their conservation

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First page: Mineralised organic remains on copper and iron bracelets, Feldkirchen 4th CE (©Marine Roux, He-Arc, 2026). All the illustrations are to be credited to ©Marine Roux, He-Arc, 2026, unless otherwise stated).

Signes: ca 95 000.

« *Il nous a paru curieux de donner ici le récit d'une fouille archéologique faite au siècle dernier, au temps du comte de Caylus et de l'abbé Lebeuf, et avec les idées qui avaient cours à cette époque. Ce sera pour nos contemporains un moyen de comparer les procédés du XVIIIe siècle avec ceux du XIXe* » (Cochet, 1857, p. 71).

Commitment

"I hereby attest this work is the result of my own creation, and it has not been presented to another jury, in part or in full. I also attest all assertions made in this text that are not the product of my own personal reflections are attributed to their sources, and all copied passages from another source are placed in quotation marks."

« *J'atteste que ce travail est le résultat de ma propre création et qu'il n'a été présenté à aucun autre jury que ce soit en partie ou entièrement. J'atteste également que dans ce texte toute affirmation qui n'est pas le fruit de ma réflexion personnelle est attribuée à sa source et que tout passage recopié d'une autre source est en outre placé entre guillemets.* »

Date et signature :

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Résumé

Cette étude porte sur les restes organiques minéralisés conservés sur des objets métalliques archéologiques mis au jour dans le cimetière de Feldkirchen (Allemagne). À travers l'analyse de divers matériaux organiques associés à une boucle, un encrier et un ensemble de bracelets, elle examine les défis liés à l'identification, à l'étude et à la conservation de ces restes. Depuis les années 2000, les restes organiques sont étudiés de manière plus systématique puis conservés sur les objets dans des laboratoires de conservation allemands et suisses. En France, la question des restes organiques nécessite encore un travail de sensibilisation et leur prise en charge systématique se limite à des projets plutôt ponctuels, très exigeants en temps et en moyens. Bien qu'ils recèlent un savoir scientifique important, les restes organiques minéralisés sont difficiles à comprendre pour les non-initiés, voire sacrifiés au profit des objectifs de recherche. L'une des solutions consiste à former le plus grand nombre possible d'acteurs du patrimoine : les archéologues, afin qu'ils puissent les reconnaître sur le terrain et adopter les bons réflexes ; les restaurateurs, afin qu'ils puissent les identifier en laboratoire et travailler en collaboration avec les spécialistes des restes organiques. Ce travail a été l'occasion de mettre en place des méthodes de documentation développées spécifiquement pour l'étude puis l'interprétation de ces restes. Il a suivi une méthodologie présentée dans une première partie menant à la création d'une documentation détaillée des restes organiques préservés de Feldkirchen pour aboutir à la proposition de traitements de ces objets métalliques au regard des restes organiques et se propose de faire part des observations faites sur le processus de préservation : la minéralisation.

Abstract

This study focuses on mineralised organic remains preserved on archaeological metal objects unearthed at the Feldkirchen cemetery (Germany). Through the analysis of various organic materials associated with a buckle, an inkwell and a set of bracelets, it examines the challenges involved in identifying, studying and conserving these remains. Since the 2000s, organic remains have been studied more systematically and then preserved on the artefacts in German and Swiss conservation laboratories. In France, the issue of organic remains still requires further awareness-raising, and their systematic management is limited to rather ad hoc

projects, which are highly demanding in terms of time and resources. Although they hold significant scientific value, mineralised organic remains are difficult for the uninitiated to understand and are sometimes even sacrificed in the interests of research objectives. One solution is to train as many heritage professionals as possible: archaeologists, so that they can recognise them in the field and adopt the correct procedures; and conservators, so that they can identify them in the laboratory and work in collaboration with specialists in organic remains. This project provided an opportunity to implement documentation methods developed specifically for the study and subsequent interpretation of these remains. It followed a methodology outlined in the first part, leading to the creation of detailed documentation of the preserved organic remains from Feldkirchen, culminating in proposals for the treatment of these metal objects in light of the organic remains, and aims to share observations made regarding the preservation process: mineralisation.

Zusammenfassung

Diese Studie befasst sich mit mineralisierten organischen Überresten, die auf archäologischen Metallgegenständen erhalten sind, die auf dem Friedhof von Feldkirchen (Deutschland) ausgegraben wurden. Anhand der Analyse verschiedener organischer Materialien, die mit einer Schnalle, einem Tintenfass und einer Reihe von Armbändern in Verbindung stehen, untersucht sie die Herausforderungen bei der Identifizierung, Erforschung und Konservierung dieser Überreste. Seit den 2000er Jahren werden organische Überreste in deutschen und schweizerischen Konservierungslabors systematischer untersucht und anschließend auf den Artefakten konserviert. In Frankreich muss das Thema der organischen Überreste noch stärker ins Bewusstsein gerückt werden, und ihr systematischer Umgang beschränkt sich auf eher punktuelle Projekte, die einen hohen Zeit- und Ressourcenaufwand erfordern. Obwohl sie einen bedeutenden wissenschaftlichen Wert besitzen, sind mineralisierte organische Überreste für Laien schwer zu verstehen und werden manchmal sogar zugunsten von Forschungszielen geopfert. Eine Lösung besteht darin, möglichst viele Fachleute im Bereich des Kulturerbes zu schulen: Archäologen, damit sie diese Überreste vor Ort erkennen und die richtigen Vorgehensweisen anwenden können; sowie Restauratoren, damit sie diese im Labor identifizieren und mit Spezialisten für organische Überreste zusammenarbeiten können. Dieses Projekt bot die Gelegenheit, Dokumentationsmethoden anzuwenden, die speziell für die

Untersuchung und anschließende Interpretation dieser Überreste entwickelt wurden. Es folgte einer im ersten Teil dargelegten Methodik, die zur Erstellung einer detaillierten Dokumentation der erhaltenen organischen Überreste aus Feldkirchen führte und in Vorschlägen für die Behandlung dieser Metallgegenstände unter Berücksichtigung der organischen Überreste gipfelte; Ziel ist es, die Beobachtungen zum Erhaltungsprozess – der Mineralisierung – weiterzugeben.

Introduction

In the global archaeological context, organic materials are often presented as scarce, especially in our part of the world, where the climate is less conducive to their preservation. Although they are less abundant than typical archaeological materials such as ceramics, metal, or stone, organic materials are by no means absent. In fact, there might be more of them than meets the eye. However, the preservation of organic materials requires specific environmental conditions since they are particularly vulnerable in the face of external environmental threats and prone to rapid deterioration. If preserved, it is likely no longer in its original form and composition.

These specific conditions are characterised by a reduction in, or an absence of, agents that degrade organic matter: dry and airy conditions, dry and cold conditions, dry and hot conditions, freezing conditions. These environmental conditions are rare to find under our latitudes. Anaerobic conditions, waterlogged conditions, and charred organic material are more often found in Europe. However, preservation in the context of metal object is one of the most often found forms of organic material remains (Moulhérat, 2008, p. 30). This type of preservation is mainly found in funerary contexts, as the organic material must be found close to a metal object, providing for corrosion and, with copper and lead, a toxic environment for microorganisms. It is through this process that organic material remains were preserved on the surface of metallic objects discovered during a salvage excavation in Feldkirchen (DE) in 1998. A buckle, an inkwell, and a group of bracelets, all made from copper (alloys), were selected for this work's case studies. This work aims to outline the challenges raised by the presence of organic material on a metallic archaeological artefact as regards its study and conservation.

First, we will present the methodology applied for this work, that is to say, the steps of this study and the resources used to carry it out. The following three chapters will then be devoted to presenting the current state of knowledge regarding mineralised organic remains, covering their definition, their consideration, an explanation of the chemical processes involved, and current conservation practices. Finally, following a chapter introducing the case studies, the conservation decisions taken for three types of objects will be presented and discussed.

The objectives are the conservation of the bracelets, one of the three types of metal objects concerned by the work. They will be exhibited in September in a museum in Aschheim on the occasion of a thematic presentation of artefacts from the collection focusing on textile remains. The documentation of the associated organic remains for each of the objects and the conservation report must be handed to the museum afterwards.

This work is supervised within the *Archäologische Staatssammlung* by Dr. Catharina Blänsdorf, head of the conservation department as internship supervisor, and Cristina Mazzola, conservator of the conservation department as mentor regarding the organic remains study.

I. Methodology

This work, carried out during the final internship of a master's program in conservation, aims to present a reflection on the key issues in conservation raised by the discovery of organic material remains on metallic objects from Feldkirchen. The objects were selected by the archaeologist in charge of the Roman collection, Dr. Bernd Steidl. Their variety found on several artefacts from the same archaeological context has led to the idea of presenting case studies of the conservation decisions taken in light of current concerns about mineralised organic remains.

The first stage of this project was to assess the current state of the subject through a literature review and interviews with an expert on archaeological textiles and a conservator. Whilst the literature helped to shed light on past practices and how these have evolved since the earliest concerns, the interviews offer a more comprehensive overview of current practices regarding these organic remains. The discussion with Sabine Brechbühl Trijasse, conservator at the Archaeological Service of the Canton of Bern, gave us an insight into how organic remains are handled there. The discussion with Dr. Émeline Retournard, textile archaeologist from the University of Clermont Auvergne (UR 1001 CHEC). provided an opportunity to gain an overview of the situation in France regarding the management of mineralised organic waste, particularly textiles. These oral interviews had not fixed questions.

The second stage of this work consisted of the observation and the study of the object using different observation and analytical methods. The aim was to gather as much information as possible and to propose the appropriate conservation treatment after assessing the state of each object. To do this, objects and mineralised organic remains were examined by observation with the naked eye, with different magnifying devices, and analytical methods.

The last stage of this study was to present the observations made, enabling a final reflection on the comparison between bibliographical and practical observations. The result will shape treatment proposals and the conservation work.

The instruments used for studying the objects were:

- A stereomicroscope (Olympus SZ40, 6,7x - 40x) equipped with a mount adapter (Olympus U-PMTVC) for a digital camera (Olympus DP26) linked to the Olympus Stream

Basic software was used to observe, document, and carry out most of the dimension and angle measurements.

- A digital microscope (Keyence VHX-6000, 0.1x - 5000x) was used to realise better quality images thanks to the stacking mode when the binocular was insufficient (Fig.1).
- A polarised-light microscope with a transmitted light illumination (Leica DM 2500 P) was used for the identification of fibres which were not or only a little mineralised.
- A scanning electron microscope (SEM) equipped with energy-dispersive X-ray spectroscopy (EDS) (Phenom ProX G7 Desktop from Thermo Fisher Scientific) was used for imaging and elemental analysis (Fig. 2, p. 13).
- XRF elemental and semi-quantitative analyses were done with the XRF Niton™ XL3t analyser from Thermo Fisher Scientific, providing information on the composition of the studied materials.
- A X-ray scanner.

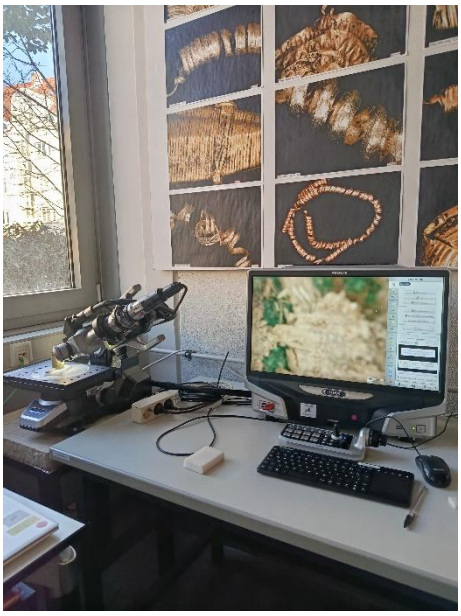


Figure 1: Digital microscope device.

For some of these analyses, sampling was necessary and carried out with approvals. Samples were collected in the quantities required by the chosen analysis method using clean tools (scalpel, needle, entomologist tweezers) and prepared according to the analysis used.

For analysis in the SEM-EDS, micro-fragments were placed on an SEM stub maintained in place by carbon tab. To ensure proper adhesion of the sample, they were left for 24 hours, then blown out with pressurised air to ensure that no lose fragment was left that could damage the device. A coating with a conductive layer like carbon was not necessary, as the samples were quite small and placed on a conductive carbon adhesive. Additionally, a "charge reduction sample holder" was used, which is equipped with a metal plate that draws electrons out (Fig. 3, p. 13). This prevents the build-up of disruptive electron charge on the sample surface, which would otherwise distort the image.

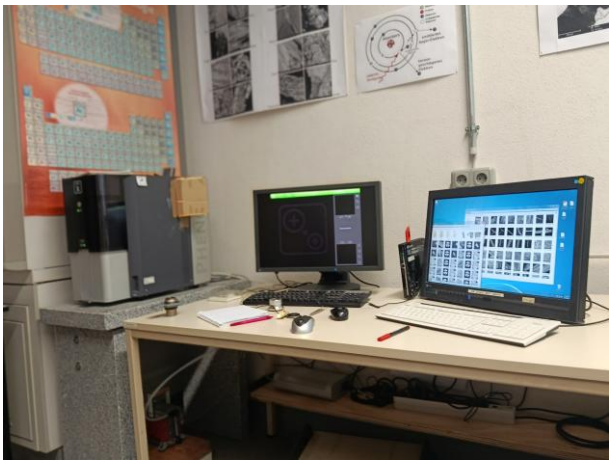


Figure 2: SEM-EDS device



Figure 3: SEM stub holder

For the polarised microscope, the sample fibres are put on a microscope glass slide, separated as much as possible to give good results and covered with a coverslip. Subsequently, they are heated to 60-80 °C on a hot plate for embedding with Meltmount™ 1.662. The resin is applied as droplets along one side of the coverslip and seeps between the two slides through capillary action. The mounting medium is selected based on its refractive index, which must differ from that of the fibre being observed. Otherwise, the sample is not visible (Fig. 8).

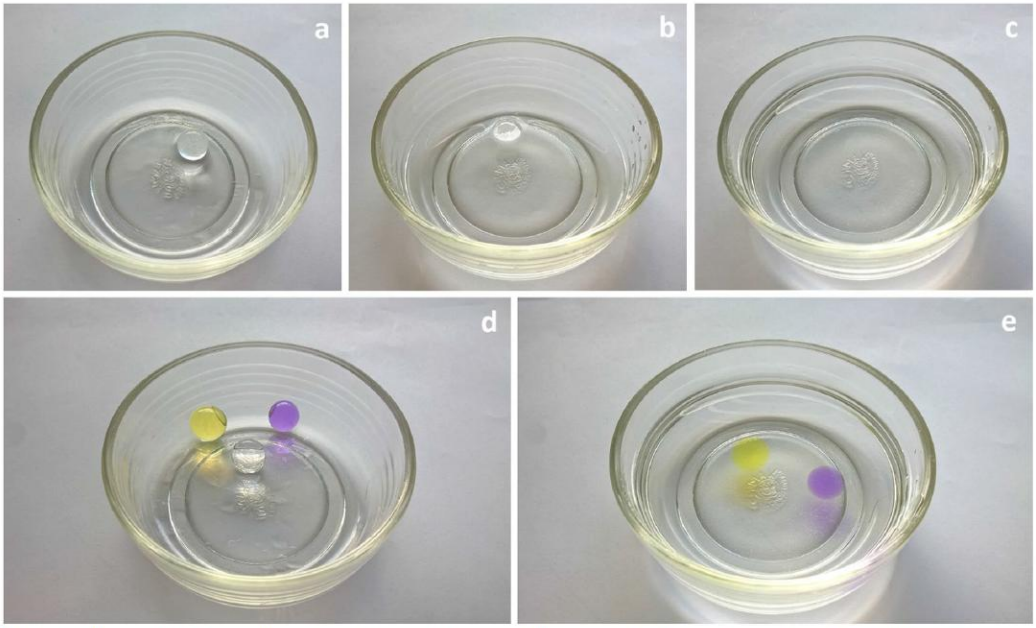


Fig. 6 The difference between refractive indices of a transparent object and its mounting medium is crucial for the object's visibility: **a** Left above: A gel bead is surrounded by air; **b** middle above: the same bead is half sunk in water—only its upper part, which is surrounded by air is visible; **c** right above: the same bead is completely sunk in the water and is not visible, because refractive indices of the bead and water are too similar. **d** Bottom left: Two coloured beads and one transparent bead are surrounded by air. **e** Bottom right: The three beads are completely sunk in water—only the two coloured ones are visible with blurred edges. The edges are blurred because there is only colour contrast and not phase contrast, © Lukesova

Figure 4: Demonstration of the refractive indices of the mounting resin when chosen by Luksesova and Holst (2024, p. 8) ©Lukesova

For textile study, it is recommended to sample from each thread system studied. The thread systems[1] of a textile are, when identified, the warp and the weft of the textile. Examples of textiles with different fibre natures between warp and weft exist. Therefore, they should be systematically both investigated when it comes to fibre identification. The two samples can be placed on the same stub and the same glass plate only if it is properly marked.

The last stage of this study was to present the observations made, enabling a final reflection on the comparison between bibliographical and practical observations.

The documentation and observation reports have been produced in accordance with both the criteria of the HE-Arc and of the institution. Additionally, the institution's procedures for referencing files and documents have been followed, and their standard report forms have been employed (treatment report, organic documentation report, etc)[2]. It should be noted that

[1] Can be noted TS of FS that stands for *Fadensystem.*
[2] See Appendix p.76.

the objects are primarily referred to by their restoration number[3], as their inventory number was assigned only at a late stage.

The documentation method used at the ASM was developed by the *Bayerisches Landesamt für Denkmalpflege* (BLfD, 2014, p. 1)[4]. This documentation method implements computer-aided design for the mapping and microstratigraphy of organic remains. It offers an automatic and standardised system for mapping in Adobe Photoshop® via free downloadable plug-ins found on their website[5]. Additionally, an explanatory document is provided, that offers a step-by-step-support for setup and application. The advantages of this documentation method are a uniform documentation and presentation, an easy comparability of organic finds between objects in the same grave, between graves, and even between excavation sites (BLfD, 2014, p. 3). At the ASM, once finished, this mapping and stratigraphy is integrated into a standardized data sheet that describes the organic material in depth along with the analytical results and conclusion. Each material found is named and described in a table, textile layers have a description part which gathers all the specific technical data required for their study, and each sample on the object is listed and presented along with the imagery and analysis results carried out.

[3] i.e., Rest. Nr.

[4] *Bayerischen Landesamt für Denkmalpflege*, the Bavarian State Office for the Preservation of Historical Monuments.

[5] Available from: https://www.blfd.bayern.de/information-service/fachanwender/index.html#navtop following section "Bodendenkmalpflege"under the tab "Hochschulen, Museen, Sammlungen, Heimatpflege".

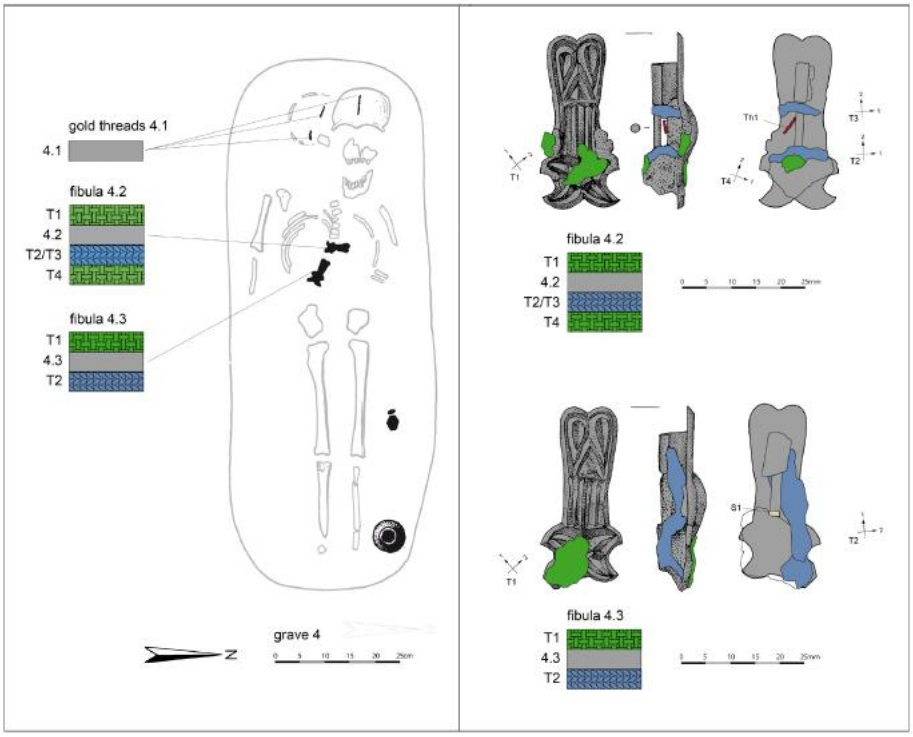


Figure 5: An example of a stratigraphy realised with the BLfD method mapping on a grave scale of Unterhacing excavation, Munich, grave 4 (BLfD, 2024, p. 1) ©Voss/Nowak-Böck, BLfD.

The steps for the study of mineralised organic remains can be summarised as follows:

- Surface cleaning;
- Documentation including sampling and analysis;
- Interpretation on the scale of the object, then on the scale of the tomb, then on the scale of the excavation site if possible.

However, the objective of this work is not to present an exhaustive historiography of the study of mineralised organic materials. This work was carried out during a five-month internship, the duration of which was determined by the requirements of the master's programme. The time constraints involved in carrying out this work also influenced the conservation decisions. Finally, the objects do not represent all possible mineralisation processes or all the materials that might be found. Thus, these case studies can only show a section of the study of organic materials preserved in the context of metallic objects.

II. Definition and considerations

2.1. Definition and terminology

A common vocabulary is a main issue for the advancement of research and the transmission of current observations. This is true among both contemporary professionals and in relation to those working in the early stages of the discipline. Chave et al. (2024) emphasise the importance of early texts for modern research, even when some of the terminology requires modern interpretation. These texts are sometimes the sole record of organic remains since lost to former conservation practices (Carré et al., 2018, p. 44). The terminology has evolved. Terms that were used to write about the mineralisation of organic materials were influenced by knowledge from different fields.

Around the 18th, the first mentions of mineralised organic materials referred to an "imprint". This term was used to describe their presence without distinction between an actual imprint and the remains of organic material, which are still intact but differ in a composition that is no longer organic (Chave et al, 2024, p. 308). This was a good hunch, as some mineralisation does indeed take the form of an imprint, a process that will be explained later. Progressively, during the 19th century, with many more descriptions and the growth of interest in mineralised organic remains, attempts to explain the process of mineralisation were shared between several scientific fields[6]. The word "petrification" was used to describe the fossilisation mechanisms described since Antiquity, which literally means "becoming stone" (Chave et al, 2024, p. 308). Some scholars even refer to a term used in alchemy*[7], "transmutation", to describe the fossilisation processes (Chave et al, 2024, p. 309). However, it is in the collaboration of the humanities and natural sciences that many theories were put forward. The observation of wood petrification and the fossilisation of other living creatures found in the coal-bearing soil, heavily exploited during the Industrial Revolution, led to the term

[6] See next chapter 2.2.

[7] Words with a star is defined in the glossary p. 67. having the form of a ring with a small break in the circumference.

"mineralisation" in archaeology and natural sciences. Since the beginning of the 20th, it began to be used extensively and still means the conversion of organic systems into mineral systems (Chave et al, 2024, p. 310). These fields shared a common interest and evolution until the 19th century when, as explained by Chave et al. (2024), "*the division between the natural sciences and the humanities, and more precisely between natural history and human history, which separated geology from archaeology from the 19th century onwards, may have obscured our understanding of mineralised textiles*" (p. 311). Beside "imprint", the term "pseudomorphosis" used in the 19th and 20th centuries refers to substances replacing one another and is used to refer to the petrification of wood and shell fossils. It means "*bodies which have a false and deceptive figure*" (Chave et al, 2024, p. 310). From the second half of the 20th century onward, "mineralisation" predominates to describe this kind of process of preservation (Chave et al., 2024, p. 312) in the French speaking countries. "Pseudomorphosis" seems to be preferred by English speaker (Gillard et al, 1994; Scott, 2002). However, as the process is becoming better understood, new interpretations have appeared to describe the different types of mineralisation processes. For example, "pseudomorphosis" is used to describe what is known as positive mineralisation (Scott, 2002, p. 75) and "imprint" is used to describe what is known as negative mineralisation (Chave et al, 2024, p. 308).

For our work, we shall retain this definition given by Gillard et al (1994): the mineralisation is "*the combination and/or replacement of the organic matrix of the fibre with an inorganic one*. *This is in contrast to the term pseudomorph, which is commonly applied to mineralised fibres and is defined as the total replacement of the organic matrix with an inorganic one"* (p. 132).

2.2. Considerations in archaeological studies through history

In their 2024 article, Chave et al. trace the origins of the interest and perception of antiquarians and early archaeologists in mineralised textiles over time. Despite the comprehensiveness of this analysis, its geographical scope only concerned France, Switzerland and the United Kingdom. Furthermore, this article focuses primarily on references to mineralised textiles. As we shall see, the growing interest in mineralised organic remains appears to be linked to the development of textile archaeology. Another geographical point of

view is brought by Carré et al (2018), who present some advances in Germany. Despite their emphasis on findings from Merovingian graves, they provide general insight into the evolution of interest in organic material remains in France, Switzerland and Germany.

Chave et al. (2024) track the origins of scientific and archaeological interest in mineralised materials back to the early 16th century, where fields of natural history and archaeology intersected. Researchers sought both data on ancient civilisations and an understanding of the preservation mechanisms at play (Chave et al, 2024, p.311). They identify the earliest description of mineralised organic remains in an archaeological report from 1730 by the English physician and antiquary Cromwell Mortimer (Wikipedia contributors 2024).

Many mentions and descriptions of mineralised organic remains, particularly textiles, were published in excavation reports throughout the 19th century, alongside the development of archaeology as a scientific discipline. In 1880, the French archaeologist and anthropologist Eugène Perron (Perron, Eugène - Archives du musée d'Archéologie nationale [no date]) marked a turning point in the study, laying the foundations of the description of archaeological mineralised textiles by publishing his results on the textiles and organic remains from Iron Age wagon-graves from Apremont[8] (Chave et al, 2024, p. 304).

However, the separation of the natural sciences and the humanities in the 19th century slowed interest in mineralised organic material remains (Chave et al., 2024, p. 311) as both fields shared an interest in the subject until then. After that, research in textile archaeology emerged as a driving force behind the growing interest in mineralised organic material remains. In the 1930s, textile archaeology kept emerging in the hands of women such as Grace Mary Crowfoot, a British archaeologist and a pioneer in the study of archaeological textiles (Wikipedia contributors 2026), and Vivi Sylwan, a Swedish textile historian and textile curator (Wikipedia contributors 2025). Grace Mary Crowfoot published innovative studies about European and Middle East textile along with her textile manufacturing works. Vivi Sylwan described textiles excavated on the Silk Road, some of which were mineralised.

The 1960s saw a significant advance in the observation and description of archaeological material. Leo Biek is presented as the pioneer of detailed microscopic description of archaeological textiles and other organic material, thanks to his book

[8] Haute-Saône, France.

Archaeology and the Microscope: The Scientific Examination of Archaeological Evidence, published in 1963. He introduced the terms "pseudomorphism" and "mineralisation" for the description of mineralised textiles and organic materials and contributed to their broader use in the field (Chave et al, 2024, p. 310).

In France, the work of Edouard Salin and Albert France-Lanord paved the way in the study and conservation of archaeological artefacts and associated organic remains. As early as the 1920s, Edouard Salin incorporated the microscopic examination of remains into his archaeological research. Together with Albert France-Lanord, he founded the *Laboratoire d'Archéologie des Métaux* (LAM)[9], a laboratory dedicated to the conservation of archaeological and historical objects, primarily made of various metals and other materials (glass, ceramics, bone, etc.). They took a keen interest in textiles and mineralised organic remains. In 1998, France-Lanord, along with Michl Fleury, published its findings from the excavation of the Basilica of Saint-Denis, notably including a reconstruction of Queen Arégonde's burial attire from the Merovingian necropolis, since re-evaluated (Carré et al. 2018, pp. 38–39). Indeed, the interpretations had been carried out without the involvement of "textile experts", which had led to incomplete results. Preserving the organic remains in boxes made it possible, nine years later, to propose a new interpretation (Carré et al., 2018, p. 39). The period from the 1960s to the 1990s was a period of development in sampling methods, study and conservation methods, including the development and use of block sampling leading to laboratory excavation techniques (Carré et al., 2018, p. 39).

In 1954, the *Centre Internationale d'Études des Textiles Anciens* (CIETA)[10] opened in Lyon, whose aim is to explain manufacturing techniques and define a common vocabulary (Carré et al, 2018, p. 41). But there was no study of mineralised textiles by CIETA. The scholars needed to call upon the expertise of textile industry specialists to conduct the technical studies, such as Hubert Masurel, a retired industrialist who studied the collections at the *Musée d'Archéologie Nationale*[11] in Saint-Germain-en-Laye (Carré et al, 2018, p. 41). The development of the discipline finally led to the training of specialists.

[9] Laboratory of Metal Archaeology.
[10] International Centre for the Study of Ancient Textiles (Website: https://cieta.fr/).
[11] National Museum of Archaeology.

In the 1990's, the beginning of SEM's application to archaeological research purposes, and specifically to textile study, is a milestone in this domain. The enhanced precision rendering of the surface, coupled with the increased depth of field, leads to a better distinction between the various fibres and materials employed (Carré et al. 2018, p. 41). Many textile and organic material studies in several excavation sites were conducted, especially in Switzerland (Carré et al. 2018, p. 41) but also in Great Britain, e. g. the work of Robert Janaway. The stakes in textile archaeology are still driving mineralised organic materials research. A resurgence of interest has been evident in recent years, since the mid-2000s, according to Elsa Yvanez, since the opening of the Centre for Textile Research (CTR) at Copenhagen University in 2005, which has boosted research into textile archaeology in Europe (*Textiles au Soudan : une archéologie sur le fil* 2026).

Since then, the issue of mineralised organic remains has remained a relatively recent one and is still treated differently from country to country. Whilst at the ASM a conservator is employed full-time to study organic remains, the *Service Archéologique de Berne*[12] has no in-house specialists but calls upon external consultants working on a freelance basis when mineralised organic remains are found during excavations or fortuitously during restoration work. At the service, the decision to carry out such a study and to preserve these remains is taken in consultation with the archaeologist, based on the archaeological significance of the find and the relevance of the study. Such studies are therefore not carried out systematically, but organic remains are highly valued and usually kept on the object when detected[13]. Sabine Brechbühl Trijasse highlights the close collaboration between archaeologists and curators in light of the recognised importance of mineralised organic remains since she began working in the field some 20 years ago. Emeline Retournard describes a more nuanced approach to mineralised organic remains in France. Textile archaeologists must adopt an educational approach to highlight the scientific value of mineralised organic remains, which are often put against metal objects. Ultimately, whether these remains are taken into account depends on the archaeologists' speciality and the subject of their study, the weight of the conservator's opinion, and established practices that are not always questioned. Emeline Retournard regrets the lack of synchronisation in research, which often separates the study of the artefact from that of the mineralised organic remains, rendering the results less relevant and potentially

[12] Archaeological Service of Berne
[13] Personal communication with Sabine Brechbühl Trijasse, 20.05.2026.

amounting to a waste of time. All these issues must, of course, be viewed within the social and economic context of archaeological research today in each country. The tendency is towards an ever-greater emphasis on organic remains, and above all, towards decisions aimed at leaving organic remains in situ on the artefact. The issue of the conservation of organic remains from the excavation to the laboratory is discussed later in this work[14].

2.3. Scientific value of organic remains

Mineralised organic material has a high informative potential. Long regarded merely as sources of technical data, without any understanding of their nature or function, mineralised textiles and other organic materials offer an additional source of information to address questions such as the economic, social and spiritual life of a community by interpreting their presence alongside anthropological data (study of bones remains). They are all the more important given that non-mineralised organic remains are rare in European archaeological finds. Studying them is essential for developing a reliable statistical overview for comparison purposes (Janaway, 1983, p. 48).

Indeed, their presence may provide insights into natural resources management, environmental exploitation strategies, or trading (Moulhérat, 2008, p. 30). Nevertheless, it also provides insights into social class, thereby facilitating an assessment of people's wealth or power. Furthermore, it exhibits elements that provide insight into funerary practices, including specific gestures and traditional funeral attire (Carré et al., 2018, p. 37; Rast-Eicher, 2009, p. 97). Finally, it is possible to assess the technological advances of the community by giving hints about processing and manufacturing conditions as well as the technological choices of the textile maker (e.g., raw material, spinning methods, dyes…) (Moulhérat, 2008, p. 30).

In brief, organic material and textiles can provide information on:

- Agriculture and animal husbandry practices
- Economy
- Social life

[14] See Chapter IV. Conservation and practices, p. 30.

- Use within the society of clothing
- Religious and funerary practices
- Technological development

III. Organic preservation and mineralisation

3.1. The degradation of organic material and its preservation in the archaeological context

The preservation of organic materials requires specific environmental conditions since they are particularly vulnerable in the face of external environmental threats and prone to rapid deterioration. If preserved, it is likely no longer in its original form and composition.

These specific conditions are characterised by a reduction in, or an absence of, agents that degrade organic matter: dry and airy conditions, dry and cold conditions, dry and hot conditions, freezing conditions. These environmental conditions are rare to find under our latitudes. Anaerobic conditions, waterlogged conditions, and charred organic material are more often found in Europe. However, preservation through mineralisation is one of the most often found forms of organic material remains (Moulhérat, 2008, p. 30). This type of preservation is mainly found in funerary contexts, as the organic material must be found close to a metal object, providing for corrosion and, with copper and lead, a toxic environment for microorganisms. It should be noted that whilst extreme conditions mentioned above can lead to the complete preservation of organic remains, this is rarely the case with mineralisation, where only fragments are usually found.

In temperate climate zones, one of the most frequent forms of preservation of organic material in archaeological contexts is in combination with metal objects. Burials often offer good conditions for mineralisation of organic matter and better conditions for interpretation. Mineralised organic materials can also be found with hoards or in settlement finds. But it is less usual in settlements, as organic material and metal do not often come under ground in such close positions that mineralisation was possible. Because the most frequent context is graves, the following paragraphs will focus on that environment.

A grave is in the first place an environment where degradation of organic material takes place in a few years (Chave et al, 2024, p.304). In the ground, organic materials are vulnerable to chemical, physical and biological degradation processes, with biological degradation by

bacteria and fungi being the most important (Fischer, 1994, p. 9). When all the conditions have been met, the most influential element in the grave is the decomposition of the body. The steps of decomposition presented by Fischer (1994, p. 5) drive drastic changes in the environment and influence chemical and physical modifications of which surrounds it. The process can take up to 10 years in standard conditions (Fischer, 1994, p. 8).

Chemical, physical and microbiological degradation of organic material is influenced by:

- pH value of the environment (Fischer, 1994, p. 9);
- Groundwater contributing to erosion (Fischer, 1994, p. 9), to the solubilisation of metal ions, and to an environment conducive to microorganisms.
- Oxygen access and airflow that contribute to the chemical degradation of organic material by oxidation.
- Its own chemical and physical composition (Fischer, 1994, p. 9). For example, bast fibre degrades more slowly than cotton because it has a higher lignin content and a higher crystalline cellulose content (Fischer, 1994, p. 11).
- Type and presence of metal objects near them (catalysing the degradation process and influencing the pH value) (Scott, 2002, p. 76);
- Their preservation state when buried (Rast-Eicher, 2016, p. 31).
- Microorganisms thriving in this environment (Chave et al, 2024, p.304). In fact, fungi are more active under aerobic conditions, and bacteria are more active under aerobic conditions (Fischer, 1994, p. 10).

3.2. Corrosion process

Factors that influence metal corrosion are environmental conditions, the metal composition and the resulting corrosion products, as well as the manufacturing technique of the object. The soil characteristics having an impact on metal corrosion are oxygen content, water saturation, soil conductivity[15] and the pH value[16] (Fischer, 1994, p. 8). The solubility and

[15] High conductivity = high corrosion rate.
[16] The pH value of most soils lies between pH 4 and 9,23 (Fisher, 1994, p. 8).

the density of the formed corrosion layer on the metal have an impact on the corrosion rate of a metal (Selwyn, 2004, p. 122). Acidic environments promote corrosion by increasing the availability of hydrogen ions, which accelerate electrochemical reactions, while simultaneously dissolving or preventing the formation of protective corrosion layers on the metal surface (Selwyn, 2004, p. 33).

Organic materials can be found preserved in the context of iron, copper (or copper alloys), lead and silver objects (Fischer, 1994, p. 12) and rarely by calcium compounds. Iron has a higher corrosion rate as it has a more negative standard electrode potential, and because of its porous, non-protective corrosion products. In the presence of water and oxygen, iron readily oxidises to form iron oxides (e.g. magnetite) and oxyhydroxides (e.g. goethite) (Selwyn, 2004, p. 105). These corrosion products are permeable to oxygen and water, allowing them continued access to the metal core.

Copper and copper alloys generally corrode more slowly than iron. The initial formation of copper oxide (cuprite) contributes to the development of a protective corrosion layer that usually preserves the "original surface". An outer layer of more stable compounds, such as copper carbonates, phosphates or other secondary corrosion products, is usually identified on archaeological copper objects depending on the presence of anions in the burial environment (Selwyn, 2004, p.64).

Although lead is chemically reactive, it rapidly develops a dense insoluble layer composed mainly of oxides covered by carbonates (cerussite) (Selwyn, 2004, p. 122). The underground corrosion of lead alloys is generally limited in soils containing film-forming compounds such as silicates, sulphates and carbonates, as these contribute to the development of protective surface layers. However, corrosion can become significantly more severe in soils with high concentrations of organic acids or nitrates (Costa and Urban, 2013, p. 53).

Metal	Rural ($\mu m\ yr^{-1}$)
aluminum	0–0.1
copper	~0.5
iron	4–65
lead	0.1–1.4
zinc	0.2–3

Figure 6: Corrosion rates for common metals outdoors. It gives an idea, it can change according to pH or temperature (Selwyn, 2004, p. 33) ©Selwyn

In the case of silver, the metal is usually alloyed with copper. During a long period of time buried, a silver alloy object corrodes slowly and traces on its surface are preserved. This also happens in a less chloride-rich environment. These conditions can lead to the covering of the surface by voluminous corrosion products. The most current situation with silver alloyed with copper is selective corrosion. Green copper carbonate or red copper oxides

formed on the surface, preferably leading to the enrichment of the silver underlayer (Costa, 2001, pp. 21-22).

3.3. Mineralisation process

The conditions for the preservation of organic fragments in the context of metal objects are optimal when they are in immediate vicinity of each other (Fischer, 1994, pp. 3 - 5). Efficient mineralisation depends on the balance between organic degradation and corrosion processes: corrosion must occur rapidly enough for metal ions to interact with the organic material before it is completely degraded (Fischer, 1994, p. 5). The corrosion rate of the metals must in any case be higher than the degradation rate of the organic materials. Mineralisation begins shortly after burial, as soon as corrosion is initiated (Scott, 2002, p. 73).

In the presence of high humidity and an acidic environment, the metal oxidises and releases metal ions into the water in the environment. At the same time, microbial activity and chemical reactions progressively degrade the amorphous first, then the crystalline regions of the organic material, creating pathways through which the dissolved metal ions can diffuse. Metal ions subsequently precipitate on the organic material surface while also forming coordination complexes with organic macromolecules within the fibres, progressively replacing the organic matrix (Moulhérat, 2008, p. 31; Scott, 2002, pp. 72–74). The toxicity of metal ions such as copper, lead and even silver (Selwyn, 2004, p.140) inhibits microbial activity and slows further biodeterioration of the organic remains.

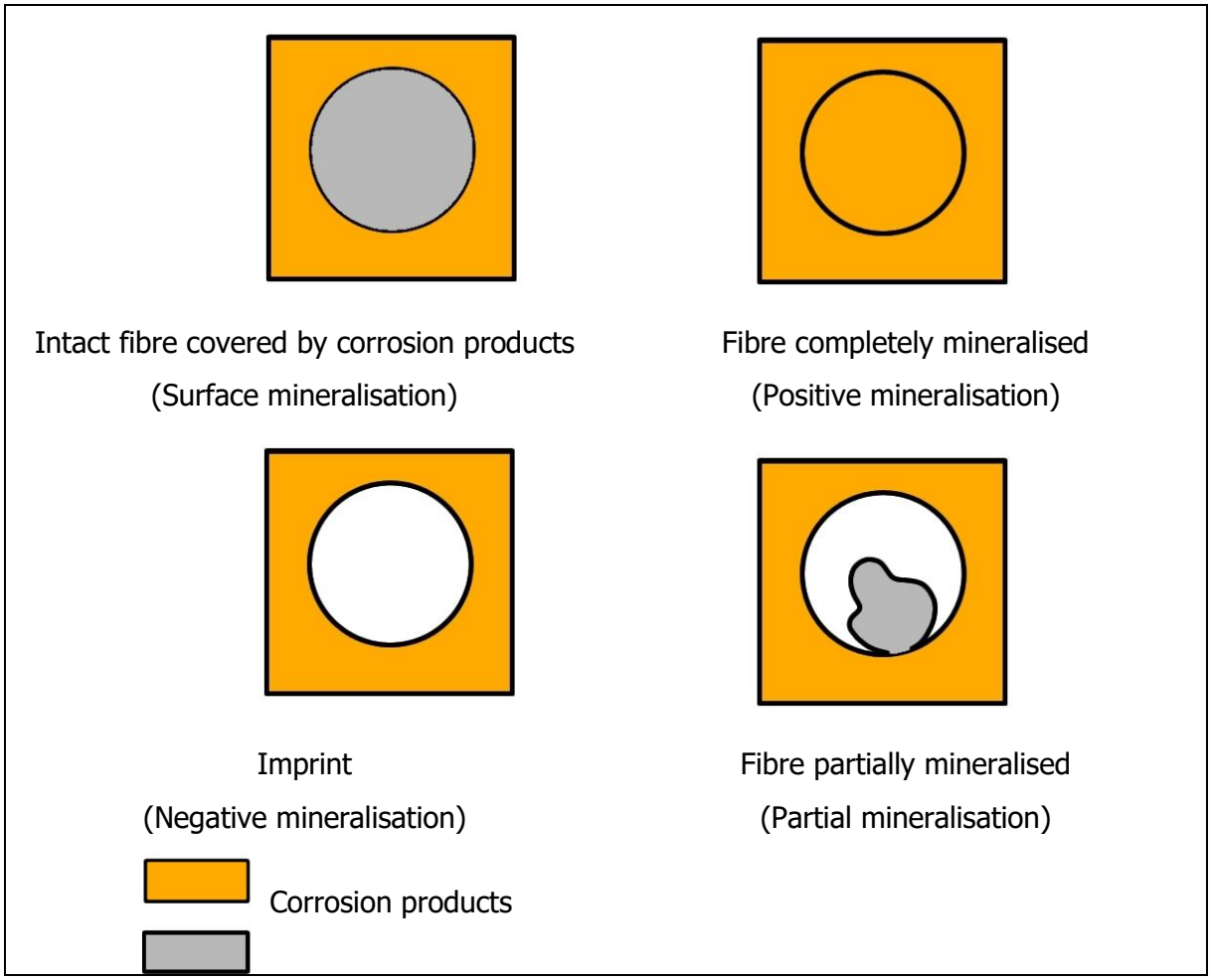
Several forms of mineralisation may result from this process (Fig. 7, p. 26):

- Surface (or superficial) mineralisation corresponds to the deposition of corrosion products on the fibre surface while the original organic material remains largely preserved (Moulhérat, 2008, p. 31). In that case, the organic material preserved a large part of its organic matter.

- Positive mineralisation, also referred to as positive pseudomorphosis, occurs when the organic material is progressively replaced by corrosion products while preserving the morphology of the original fibres (Scott, 2002, pp. 72; Moulhérat, 2008, p. 31; Chave et al., 2024, p. 304). Scott (2002) presented this case with copper mineralisation. Copper ions first bind to reactive sites within the organic matrix to form copper–organic complexes. Then, when all available sites are filled,

controlled mineral deposition occurs, initiated by the already occupied sites. Corrosion gradually replaces the fibre as it decays, forming a positive fibre cast of corrosion products. It is a much more common mineralisation type with copper than with iron.

- Negative mineralisation occurs when corrosion products accumulate around the fibre, which subsequently decomposes, leaving only an impression (or mould) of its original form (Scott, 2002, pp. 72–74; Moulhérat, 2008, p. 31; Chave et al., 2024, p. 304).
- Finally, organic material which seems still completely organic and often very degraded. It can be preserved mainly thanks to the biocidity of the metal but cannot be more than a few cm away from it.



Non-mineralised fibre textile

Figure 7: Proposed schematic representation of the various types of mineralisation according to Moulhérat (1998, p. 52).

Several forms of preservation in metal context can coexist within the same object or tomb (Moulhérat, 2008, p. 31).

Jia et al (2024) stated that as fibre mineralisation involves the progressive replacement of organic components by inorganic compounds, the carbon content of the fibres may gradually decrease, whereas copper concentrations may increase as mineralisation proceeds. This carbon presence can be measured with Fourier transform infrared spectroscopy (FTIR) to evaluate the state of mineralisation of organic remains. However, despite the widespread use of the term "complete mineralisation", FTIR studies have demonstrated that in the case of mineralised fibres generally residual organic matter is retained, often sufficient to permit fibre identification and, in some cases, dye characterisation (Scott, 2002, p. 74; Jia et al, 2024). Total replacement of the organic matrix is relatively uncommon. A study done by Reynaud et al (2020, p. 3) on a 5 000-year-old cellulosic textile highlighted the role of silica compounds from the soil in stabilising the fibre structure and the lasting preservation of organic residue despite the ancientness and mineralisation state of the sample (Reynaud et al, 2020, p. 3).

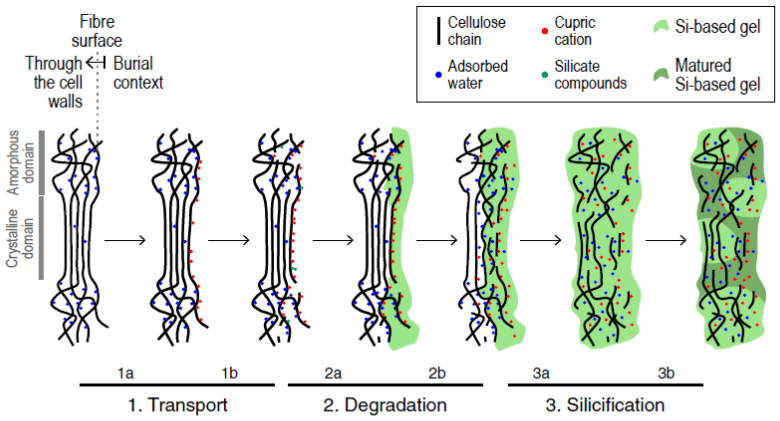


Fig. 5. Mechanism for cellulosic fiber mineralization over time. Step 1: Water transport of biocidal metal cations and soil solutes—formation of copper–cellulose complexes at the surface of the fibers (1a) and hydrolysis of amorphous compounds and condensation of silicates on fiber surface and in amorphous areas (1b). Step 2: Degradation and loss of crystallinity of cellulosic polysaccharides—degradation of the superficial macromolecules of the crystalline zones (2a) and local swelling (2b). Step 3: Silicification—diffusion of solutes deeper into the cell walls and condensation of siliceous compounds (3a) and maturation in denser siliceous phases (3b).

Figure 8: Explanation of mineralisation of cellulosic fibres (cotton, flax, hemp...) by Reynaud et al (2020, p. 5) ©Reynaud, Bertrand.

IV. Conservation and practices

4.1. Transitioning from the site to the lab

The earlier mineralised organic materials are detected in the course of action, the greater the chance they will be preserved. Particular care must be taken during excavation, but they are generally detected during laboratory conservation work, as some are invisible to the naked eye.

The safest method for lifting objects with adhering or surrounding organic remains is by block lifting. In France, this technique has been used in priority for fragile objects such as glass vessels, but rarely, if ever, for metal objects with organic remains. Its advantage is that it secures all artefacts and ensures the preservation of the position of the object and organic fragments in relation to each other. The right materials and techniques for block lifting must be used according to the artefact's fragility and its environment (Rast-Eicher, 2016, p. 55).

During the excavation, the exact position and orientation of the finds within the grave must be recorded, the upward-facing side of the object must be marked, and dark colourations in the object's surroundings with brief descriptions and detailed photographs must be noted. Dark colourations are a sign of degraded organic material. It is essential for interpreting their function to subsequently reinstate the objects in the site context (Haas-Gebhard, 2013, p. 156; Carré et al., 2018, p. 45).

It is recommended not to use any consolidant on the object before moving the blocks to the lab. Indeed, its presence, and the following application of solvent, can interfere with later analysis or damage the organic remains. Nevertheless, it seems wise to consolidate mineralised organic remains on an object, using as little adhesive as possible, e.g. in small, isolated spots, rather than risk losing the fragment whilst handling it. But it is important to thoroughly document the products used and the location of their application, so that this can be considered during later analyses. A sample can also be taken before consolidation to ensure no contamination (Gillis and Nosch, 2007, p. 10). Implementing a protocol of study and conservation should help, especially when costs and time have to be considered (Huysseune et al, 2019, p. 55). The actual amount of residues of products left and the impact in the terms of interference with some analysis if consolidant is used does not yet seem to be well

evaluated. However, some studies have been carried out, and for instance, the use of cyclododecane has little or no impact on carbon-14 dating (Bruhin, 2008, p. 110) but can stay a very long time on the fibres, interfering with SEM analysis (Rast-Eicher, 2016, p.61). This topic deserves further investigation.

Certain standard practices need to be reviewed. For example, Carré et al. (2018) questioned the practice of some archaeologists to clean the exposed surface of an object for better photographic documentation. And this is at the expense of potential mineralised organic materials (Carré et al, 2018, p. 44). Thus, metal objects should not be cleaned on site.

The excavation process has to be conducted in a laboratory setting, using a stereomicroscope and a grid-based excavation method in order to facilitate the accurate measurement of the topographical features. The objective is to ensure that the finds can subsequently be contextualised within the excavation (Carré et al, 2018, p. 39) (Fig.9).

Objects with organic remains and their containing blocks must be stored in humid and cool conditions. It has to be kept humid to avoid the soil drying and cracking, putting mechanical constraints on the object and the adhering organic material, risking damaging them. The cool environment slows their deterioration and the action of microorganisms (Haas-Gebhard, 2013, p. 13; Carré et al., 2018, p. 42). It can be stored immediately after excavation in a 4°C storage while still damp (Haas-Gebhard, 2013, p. 156), or the soil can be frequently humidified during the study and conservation work with water mixed with ethanol (Carré et al., 2018, p. 42) for the same reasons mentioned. Ethanol has a biocidal action and helps control the amount of water by evaporating faster. We want to avoid bringing more moisture onto the metal artefact because of corrosion risk. The conservation treatment of artefacts can begin as soon as the collection of information on the organic remains is done.



Figure 9: Celtic tomb of Otzing block-lifted and presented as a block in the permanent exhibition of the ASM. The organic material remains were examined in their context. (©Catherina Hess)

4.2. Current practices in conservation

Excavated metal objects are usually covered in layers of corrosion products and soil components that form gradually. This initial process of degradation is slow compared with the subsequent changes that can occur after excavation. Indeed, depending on the concentration of pollutants in the soil, and because of the sudden changes in the climate conditions (more oxygen, changes in relative humidity and temperature), corrosion generally progresses rapidly after the objects are excavated, which can lead to their disintegration. This is why conservation work is required immediately after excavation in order to preserve artefacts and slow the processes of deterioration. This ensures the artefact can be studied and preserved on a long-term basis.

Until recently, the standard practice was to remove the corrosion and clean the metal object thoroughly after studying and sampling mineralised organic materials, if ever done (Carré et al, 2018, p.41). Mechanical cleaning techniques are generally used to expose the original surfaces of the artefacts, along with supplementing chemical cleaning methods. To stabilise the object, it is important to remove any pollutants it contains and to ensure a contamination-free environment with a suitable climate. Two different approaches are possible: to implement measures that act directly on the object, and measures relating to its storage. Stabilisation is most effective when both approaches are implemented.

But the preservation of mineralised organic materials on metal artefacts is not compatible with this traditional approach of metal object conservation. The use of chemical treatment for stabilisation or corrosion removal would involve the damaging of the organic material and potentially interfere with future analysis. We have to keep in mind that analytical

techniques are continually evolving and could give new results over the coming decades. Nowadays, the decision to keep organic material on the object is increasingly being proposed, if not the most common approach.

Before the study, it is necessary to clean the organic deposits to improve their visibility and their understanding. This is done with fine brushes, entomologist needles, wood rods and under a stereomicroscope (Haas-Gebhard, 2013, p. 156). A mixed solution of ethanol and demineralised water 50/50% (w/w) can help to remove the dried and adhering soil but must be used to a limited extent without wetting the mineralised organic part or the object. The presence of moisture may accelerate corrosion, whereas the solvent may adversely affect organic fibres, e. g., ethanol can extract residual dye compounds from textiles.

Concerning complex stratigraphy and covering corrosion, the two possibilities are to decide to remove layers if necessary or simply work with available information. The decisions must be taken regarding the preservation state and the organisation of the mineralised organic material layers, to decide whether it is necessary to clarify a complex stratigraphy or not (Haas-Gebhard, 2013, p. 156). In any case, these interventions are not reversible and must be carefully considered.

After the study of the organic material, the question of preserving the mineralised organic remains on the object is raised. As said earlier, the custom tends to the preservation of the mineralised organic material on the object. But the choice of treatment depends on several factors:

- The assessment of the scientific and historical value of both organic material and metal objects.

Organic remains, which are rarer than metal objects, are often of greater scientific interest. For example, Early Medieval buckle plates are well known to the Service Archéologique de Berne and will not be affected by a part of their surface being covered with mineralised organic remains[17]. Analytical techniques now make it possible to observe, in a way, the decoration and other technical data of metal objects and to assess their state of preservation before removing the corrosion. X-ray images or neutron tomography are sufficient to retrieve the needed information, allowing a typological classification (Haas-Gebhard, 2013, p. 18). However, the

[17] Personal communication with Sabine Brechbühl Trijasse, 20.05.2026.

discovery of a type of metal object that is rarely found or that displays new technical characteristics may take precedence over the preservation of the associated mineralised organic remains on the object (Haas-Gebhard, 2013, p. 17).

- The chemical and physical stability of the metal object.

Keeping the mineralised organic materials on the object depends on the chemical and physical stability of the metal artefact. As it is their support, the degradation of it means the disappearance of mineralised organic materials. When the object's stability is at stake, the balance between the scientific value of the mineralised organic remains and that of the metal object is no longer the only factor influencing the choice of conservation treatment. At the risk of damaging the mineralised organic remains, the metal objects must be treated to remove pollutants that threaten their integrity and that of the mineralised organic remains. This is for example, the case for iron artefacts, for which the corrosion process can proceed almost in fast-forward after excavation. The organic remains are secured during the desalination process with a temporary protective covering containing a consolidant (Haas-Gebhard, 2013, p. 156).

- The exhibition of the object.

If the object goes back to the storage facility, the question of its presentation does not arise. But how to present it to the public, keeping all the organic material in place? If the object is to be displayed in an exhibition, its crusty appearance must be explained to visitors who are not used to it (Carré et al, 2018, p. 45; Haas-Gebhard, 2013, p. 17).

Depending on these factors, three choices can be made:

- Complete removal of the organic remains.

This was the decision taken at the time of a new evaluation of the artefacts from the Gallic necropolis at Bobigny[18], 15 years after the excavation, with the aim of carrying out a systematic study of the metal artefacts and their systematic conservation. The archaeologist who was in charge of the studied objects was specialised in metal objects. Studies of mineralised organic remains were carried out before conservation treatments of the metal objects, as these

[18] Seine-Saint-Denis, France. Excavated in 2002 and 2003 as part of a rescue excavation.

involved the total removal of corrosion. Priority was given to the archaeologist's examination of the object's surfaces free of corrosion. The conservation work focused on cleaning them for chronotypological study purposes and ensuring a long-term conservation by carrying out consrvation treatments (Huysseune et al, 2019, p.55, 57). The stance taken is somewhat like that of preventive archaeology, which aims to undertake the scientific study of archaeological remains that might otherwise be destroyed.

- Partial removal of organic remains.

Partial removal of the mineralised organic remains is another option. The scientific and aesthetic value is reassessed based on parts of the object and the mineralised organic remains covering areas of interest. So, at the ASM, the shiny gold or silver surface of fibulae has long been preferred to the crusty appearance of the layer of mineralised organic remains. A conservation compromise was reached by leaving the mineralised organic remains on the reverse and completely exposing the front (Haas-Gebhard, 2013, p. 17).

- No removal of the organic remains.

Today, at the ASM, mineralised organic remains tend to be kept on the object as a standardised decision in their entirety. Technological studies rely on imaging techniques that allow a non-invasive observation and on windows opening into the corrosion avoiding mineralised organic remains to understand how artefacts were made (Haas-Gebhard, 2013, p. 156).

It is rare for a decision on treatment to be reached unanimously for all artefacts from a single excavation. The decision must be made on a case-by-case basis, taking into account the nature of each item and the purpose of the treatment. What is really important is ensuring that the documentation is as comprehensive and accurate as possible. Finally, as written by Haas-Gebhard (2013, p. 18) "Freilich muss man beim Belassen organischer Reste in Kauf nehmen, dass einem von Zeit zu Zeit eine Runeninschrift auf der Rückseite einer Fibel entgehen könnte hier kann man nur hoffen, im Ernstfall bei der Entscheidung „Entfernen organischer Reste oder nicht" den richtigen Riecher zu haben"[19].

[19] Translation: "Of course, when leaving organic remains, one must accept that a runic inscription on the back of a brooch might occasionally be missed. In such cases, one can only hope to have the right instinct when deciding whether or not to remove organic remains" (Haas-Gebhard, 2013, p. 18) with Deepl.com.

4.3. Challenges

The study of organic remains is heavily dependent on financial constraints. Such studies are costly and time-consuming, and can considerably extend the time taken to treat and process archaeological artefacts. It is therefore necessary to make more restrictive but essential choices to avoid rendering this essential work completely impossible.

Time constraints must also be taken into account. If specialists in organic remains are not part of the institution and work on a freelance basis, they may have less time to devote to a long-term project. This is all the more so given that there are currently few such specialists (Carré et al., 2018, p. 45).

The quantity of metal objects associated with organic remains also poses a challenge given the increasingly systematic approach to their handling. Indeed, more than half of the objects processed from the Harfleur excavation featured organic remains preserved within a metal context (Carré et al., 2018, p. 45). Henri and Retournard (2019, p. 72) also present statistics from five excavations carried out in France, showing that between 60 per cent and 94 per cent of metal artefacts are affected by the presence of associated organic remains.

V. Contextualisation of the objects

5.1. Institutional context

The objects belong to the collection of the *Archäologische Staatssammlung (ASM)* in Munich. The ASM is a museum on *Lerchenfeldstraße* and a collection that was first constituted after the donation of prehistoric finds from Johannes Ranke, a physician and anthropologist, to the Bavarian state in 1885. It expanded due to the transfer of local archaeological finds coming from other Bavarian institutions or from new excavations. The collection was moved to the current location in 1976. After 8 years of building refurbishment, the museum reopened its doors in 2024 and offers a 600 m^2 exhibition space. The ASM oversees eight branch archaeological museums in Bavaria, representing Bavarian culture throughout the region and time. A restoration workshop was created in 1930 with in-house conservators. The current conservation laboratory on *Oettingenstrasse* has been occupied since 2000 (*Archäologische Staatssammlung*). Archaeological textiles have been studied at the ASM since the 2000s by Gabriele von Looze until 2014. Textiles and, more broadly, organic remains have been studied by Cristina Mazzola, a conservator, who has implemented the BLfD methods[20].

5.2. Archaeological context

In 1998, a late antique Roman cemetery was found in the municipality of Feldkirchen during construction work on the access road to the Munich-Riem trade fair. Feldkirchen is situated on the eastern outskirts of Munich, Bavaria, in southern Germany, and lies at the northern edge of the Munich gravel plain. Since it was known that the area had the potential to yield archaeological discoveries, a salvage excavation was requested by the BLfD in relation to the construction work. The salvage excavation encompassed the identification and documentation of archaeological features, including a Roman road, prehistoric settlements and graves. It was executed by PLANVM, a private company, in the period from 12.01. to 22.04.1998 under the

[20] See Chapter I. Methodology, p. 12.

surveillance of state representatives. A total of 20 burials, which were all southwest-to-northeast-oriented, as well as two cremation graves, were identified[21].

The burials contained funerary furniture, grave goods, and fragments of clothes (Ganslmeier 1998, pp. 1–16) and could be dated to the 4th century CE, thanks to coins and ceramic vessels[22]. A total of 132 archaeological finds were retrieved from the graves, with graves containing varying numbers of artefacts. The scarcity of artefacts discovered is not unexpected. Despite the excavation report's indication of looting at the site at some point in its history (Ganslmeier 1998, p.14), the burial practices of the era are consistent with a small number of objects being placed in the tomb[23]. The discoveries include copper, iron, and silver alloy artefacts, glass beads and vessels, ceramic vessels, bone artefacts, and coins.

5.3. Objects presentation and project scope

Objects

The objects' material history since 1998 is vague. We know that the objects stayed for some years at the excavator's place. We don't know if their actual packing is the original one or if they were repacked and by whom. In 2005, the objects were regained and brought to the ASM. The objects that will be presented in this work come from different graves.

Tableau 1: Associated numbers of case studies' objects for their identification.

Name	*Restoration no.*	*Discovery no. & Grave no.*	*Find no.*	*Inventory no.*
Bracelets	2026/5943	153 (Grave 2)	112	--
Inkwell	2026/5944	117 (Grave 1)	52	--
Buckle	2026/5945	155 (Grave 5)	116	--

[21] Personal communication with Dr. Bernd Steidl, 01.04.2026.
[22] Personal communication with Dr. Bernd Steidl, 01.04.2026.
[23] Personal communication with Dr. Bernd Steidl, 01.04.2026.



Figure 10: Bracelets (2026/5943) in the polypropylene box.



Figure 11: Inkwell (2026/5944) with surrounding soil in a polyethylene plastic bag.



Figure 12: Buckle (2026/5945).

The **bracelets** came from grave no. 2 (Tab. 1, p. 35). They were worn on the left wrist. There are five bracelets, and one of which is partially missing and attached to another. For this reason, it is described along with no. 1[24]. They were numbered from 1 to 4 to ease their study because they have the same restoration number. The numbering was given according to their order in the packing box as they were lifted together and were stored in a polypropylene box with a lid. Because they were the only objects retrieved this way, this handling was likely intended to preserve their respective positions relative to one another. Their position appeared to have moved, but their order seemed to be the same as in the grave. It was determined thanks to a photographic view taken during the excavation[25]. Bracelet 1 appeared to be closer to the hand and vice versa (Fig. 13).

[24] See next Chapter VI. Observation and treatment proposals, p. 42.
[25] See Photographic Appendix, Bracelet, p. 75.

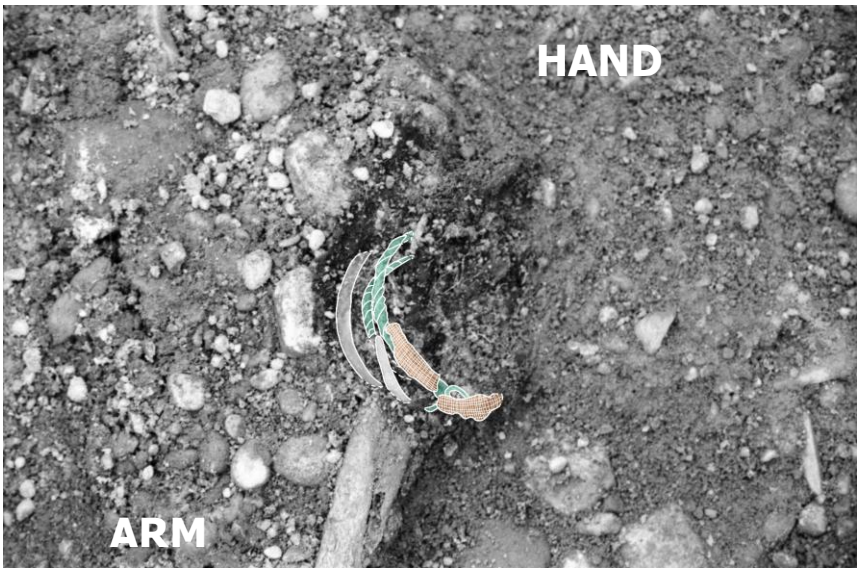


Figure 13: Highlighted location of the bracelets on the wrist. The hand has disappeard.

The **inkwell** was found in grave no. 1 (Tab. 1, p. 35). It was placed to the right of the head of the deceased, near its shoulder and a glass vessel above it. It was stored in a cardboard box with Ethafoam bedding. It has been retrieved with its contents and the soil that was around it stored in a polyethene plastic bag. This sampling is likely linked to the fact that the tomb drawing indicates that the surrounding soil was darkened.

The **buckle** comes from grave no. 5 (Tab. 1, p. 35). It was found in the abdomen area, near the inner left thigh, with the thorn facing upward. It was packed in bubble wrapping and placed in a plastic box along with some soil surrounding it. The presence of batches of black fibres interpreted as textile on the tomb drawing is likely the reason for this particular packing. Similar little objects are stored in polyethene plastic bags. These fibres are not, in fact, textile[26].

Cultural value

This discovery is scarce for the region. Other cemeteries in the area were found, but none have been fully excavated like this one[27]. Roman funerary practice favoured cremation over inhumation burials until the 3rd century CE. The use of inhumation at Feldkirchen may reflect

[26] See Documentation Appendix, Buckle, Organic documentation, p. 110.
[27] Personal communication with Dr. Bernd Steidl, 01.04.2026.

the influence of local funerary traditions or the influence of Christianity. Therefore, finding organic remains or textiles from the Roman period is relatively rare. There are no similar finds in the region for the same period (Bernd Steidl 01.04.2026). Therefore, they are of considerable scientific value. However, these objects also have a historical value, as they are to be lent to the historical and archaeological museum in Aschheim, a town near Feldkirchen, which displays the region's archaeological finds.

Scope

The scope for all the artefacts from Feldkirchen is to study and conserve them. As regards the selected artefacts, the aim is to gather information about them and the associated organic remains and to conserve them before they are lent to the AschheiMuseum so they can be exhibited there.

Initially, only the exhibition of the bracelets was discussed. The bracelets will be presented in September as part of a special exhibition showcasing the Aschheim Museum's permanent collections from a textile perspective. This event is being organised in collaboration with the Bavarian Museum in Kirchheim and is entitled "Year of Textile". The idea is to unveil the bracelets at a press conference, as they are the only items from the collection to be included in the permanent exhibition. In this respect, discussions were conducted with the museum's archaeologist, Dr. Anja Pütz. Ideally, the bracelets will be displayed on a stand that presents them in their original position. The other objects are now to be presented too, but not as soon as the bracelets. The goal is to present all of the objects of Feldkirchen at the AschheiMuseum. That is beyond the scope of this work.

The study of the organic remains began with the buckle, followed by the inkwell, as these are smaller in size and therefore easier to begin with. This allows us to wait for the documentation of the excavation report to arrive. Excavation drawings and photographs of the objects studied were kindly provided by the BLfD, owner and manager of these documents. These documents confirm that the position of the bracelet shifted from its original position and that we could start the documentation. The excavation report was available, but it is too brief when it comes to the position of the artefacts in the grave.

VI. Observations and treatment proposals for three different artefacts

This chapter aims to present the reflection concerning the conservation aspect of these objects regarding the associated mineralised organic materials. In the meantime, it proposes to confirm or question the information found in the literature and to identify the challenges posed by the presence of organic remains on a metal object.

First, the objects and organic remains had to be cleaned of the soil covering their surfaces to enable observation. The cleaning action is not reversible and must be carefully done without scraping mineralised organic material apart. The cleaning was made under a stereomicroscope using a handmade tool made of a wooden stick and an entomologist needle, applying partial humidification with a mix of 50/50 (w/w) of demineralised water and ethanol with a pencil. Ethanol helps to control the moisturising by evaporating the solution faster. The solvent excess on the pencil must be regulated before applying it to the substrate (e.g. with absorbent paper) to avoid an over-moisturising effect on the object and the mineralised organic material. The solution could damage the preserved organic part or the metal object if not stable enough[28].

The AschheiMuseum's exhibition room is situated in the cellar of an old municipal building. The climate is relatively stable. The room is fitted with a dehumidifier, and the incoming air is controlled by ventilation systems. Its location in the basement ensures stable temperatures throughout the year, with an average temperature of 22 °C, ranging from 18 °C to 25 °C; relative humidity ranges from 34% to 37% in winter and from 40% to 45% in summer. The showcases are not climate-controlled.

The condition reports and alteration mappings are presented respectively in the Documentation appendix pp. 112, 133 and 150. The organic documentation and mapping are shown pp. 119, 140, 153.

[28] See Chapter IV. Conservation and practices p. 30.

6.1. Case study 1: the bracelets (2026/5945)

Four bracelets (Fig. 14 – 17) were found around the left wrist of the deceased from the grave numbered 2 (Befund 153). They were numbered from 1 to 4 to ease their study as they have the same restoration number (2026/5945). They were stored in a polypropylene box. Bracelet 1 is the first retrieved from the box, bracelet 4 being the last. The bracelets were recovered along with bone fragments from the arm.

As these were the only items packaged in this manner, we initially considered the possibility of a block lifting that had preserved the original positioning of the elements. The discussion about whether the bracelet position in the grave was preserved when lifted kept us waiting for the photographs taken on site to be transferred from the BLfD. Unfortunately, photographs taken on-site revealed that the contents had shifted. The sediment had dried out, and no packing material had been used to secure the items.

They are typical Roman bracelets, and their typology extends beyond Roman times. The forms are known in other parts of the Roman Empire at the same period and others. There are also typical finds along the Danube River[29].

[29] Personal communication with Dr. Bernd Steidl, 01.04.2026 and Dr. Anja Pütz, 10.03.2026.



Figure 14: Bracelet 1.



Figure 15: Bracelet 2.



Figure 16: Bracelet 3.



Figure 17: Bracelet 4.

Jewellery do not have a practical function. However, they have been worn and put as grave goods by humans since Prehistory. They are made according to aesthetic choices such as the colour, the form and the trend. They can be related to gender as they can be socially representative of a community according to the material used or the type. Bracelets are often associated with women (Ganslmeier, 1998, p.14), but no anthropological study confirmed this hypothesis in this case. They also display the socio-economic group of an individual expressed by the material of choice or the hiring of a skilled craftsman. Finally, jewellery could be attributed esoteric* and prophylactic* properties, as well as other meanings that elude us (Musée de Gergovie 2026).

These bracelets are of considerable scientific value due to the presence of mineralised textile remains. Such examples are scarce for the geographical area and time[30]. Bracelet 1 is the one that exhibits the most substantial textile fragments. However, the use of diverse

[30] Personal communication with Dr. Bernd Steidl, 01.04.2026 and Dr. Anja Pütz, 10.03.2026.

materials and manufacturing techniques employed in the making of these bracelets provides an insight into the subject of late Roman metallurgy. The bracelets also have significant historical value, like the other objects from this excavation, as they will be incorporated into a regional history and archaeology museum, the purpose of which is to trace the history of the municipality through local archaeological discoveries (*Home*).

1.1.1. Descriptions

Bracelet 1 – The twisted

Bracelet 1 was made of three wires twisted together. Two are made of copper alloy, and one was made of iron. Completely corroded, it has now disappeared, leaving behind only a few scattered corrosion traces of its existence. A hook and a loop, formed by the same copper wire from the bracelet, allow it to be fastened. The other copper one wound itself around it at the end. We can imagine that the third iron one ended the same way[31].

A fragment of a darker ring made of iron adheres to the bracelets. It occupies half of the internal surface of the bracelet and goes between its ends (Fig.). A fragment of it is attached to a bulk of mineralised organic material remains. This helped to identify and put back in place this organic fragment on the bracelet and to retrieve its context regarding other mineralised textile fragments (Fig. 18, p. 42). The elemental composition of the wire surfaces was examined using non-destructive and portable X-ray fluorescence analysis (p-XRF)[32].

[31] See Documentation appendix, Buckle, Condition report, p. 103.
[32] See Analysis and observations appendix, XRF results, p. 159.

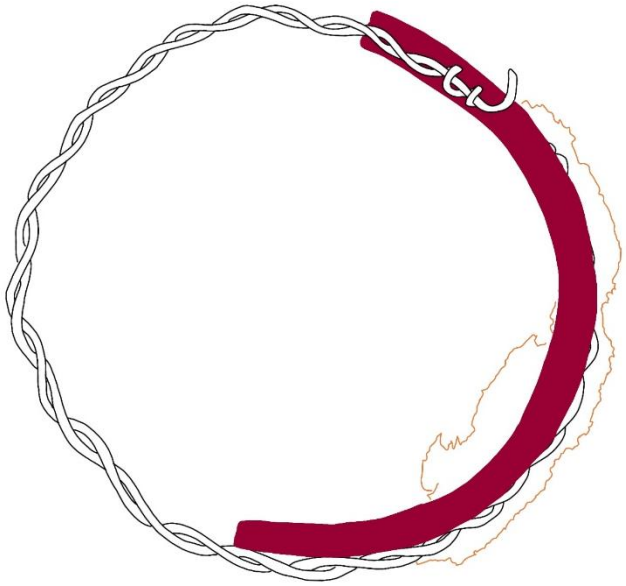


Figure 18: Fragment of a fifth bracelet made of iron shown in red. In orange, it is the location of the bigger fragment of mineralised textile. The dissociated big fragments of mineralised organic material are not shown here.

Bracelet 2 – The spiral

Bracelet 2 consists of a core metal wire around which a metal coil is wound. The metal coil has a rice-grain cross-section (Fig. 19). The fastening mechanism is made of a hook and a loop formed in the core wire (Fig. 20). The elemental composition of the wire surfaces was examined using non-destructive p-XRF[33].

[33] See Documentation appendix, Buckle, Condition report, p. 103 and Analysis and observations appendix, XRF results, p. 159.

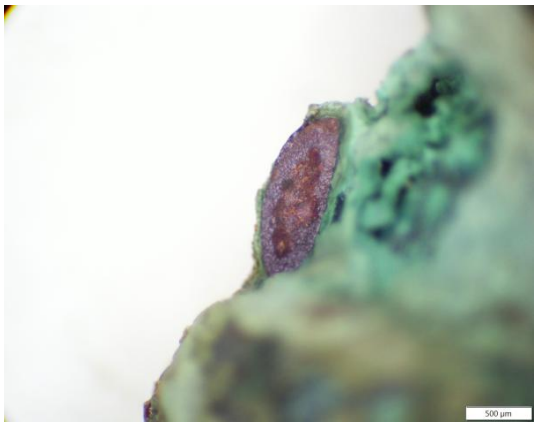


Figure 19: Cross-section of the coiled wire.

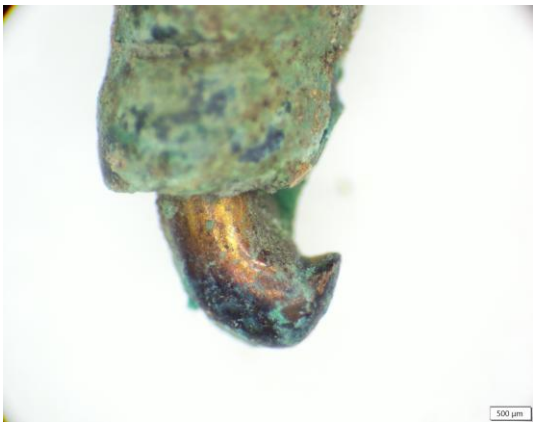


Figure 20: Hook with a well-preserved surface.

Bracelet 2 has few mineralised organic materials preserved on its surface. The only traces are textile traces mineralised by iron corrosion products situated near the loop. (Fig. 21 - 22) Due to a lack of time, these textile remains were not examined. 30% of the surface was covered by mineralised nematodes, trapped in copper and iron corrosion.

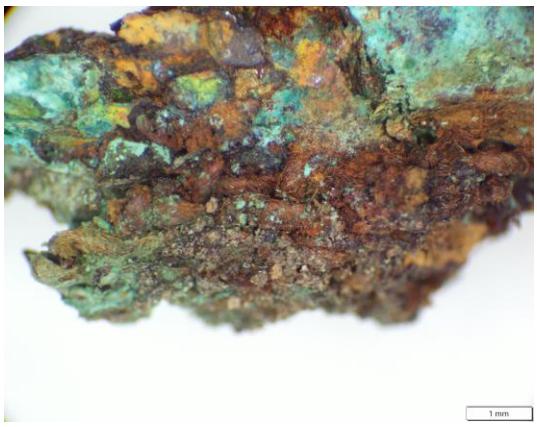


Figure 21: Textile remains.



Figure 22: Location of the textile remains

Bracelet 3 and 4 – The silver penannular* bracelets

Bracelet 3 and 4 are two C-shaped bracelets made of silver alloy. This was confirmed by p-XRF[34], and a window opening in the corrosion shows a light-grey shiny surface. A broken end of the bracelet no. 3 enables us to confirm that this is not a silvering. The opening gap is

[34] See Analysis and observations appendix, XRF results, p. 159.

smaller for bracelet no. 4. The alloy should have been flexible to allow the bracelet to be slipped on. The organic material identified on these bracelets is textiles preserved by copper corrosion. A significant proportion of the surface was covered by nematodes preserved by copper corrosion. The textiles were not examined due to lack of time, but their mapping is available in the Documentation appendix (p.112).

1.1.2. Organic material

Skin and textile fragments were identified on the bracelet. Almost all of the preserved organic remains are preserved by iron corrosion products. We can say that the deceased wore a garment made of a bast-fibre tabby-weave textile. An animal-hair textile made of simple threads and plied yarn composed either a layer of the garment or a funerary furniture. These textiles, along with skin remains, were preserved by the iron corrosion provided by an iron bracelet now adhering to bracelet 1.

Two different types of tabby-woven textile cover a part of the bracelet, composed of approximately six layers. A third one has been identified only on the organic fragments found separated from the bracelet that also include the two mentioned textiles. It is also only on these fragments that there are skin remains. The first two textiles are made with bast fibres (maybe flax). Their proximity and the folds could suggest that these two pieces of fabric come from the same textile. However, the difference in their state of preservation suggests that they are, in fact, two different textiles. The one closer to the metal presents two types of preservation: showing little mineralisation, and by positive mineralisation. Some fibres are still flexible. The one a layer apart from the bracelet is preserved mostly by negative mineralisation and is covered by a hard layer of iron corrosion products. The third one is made of animal fibres (maybe wool) and is a tabby weave with a thread system made of plied yarn, whereas the second thread system is made of a single Z-spun thread. It is preserved by negative mineralisation. On the bracelet, a further layer of metal is a very degraded textile[35].

The skin position on the fragments seems to come from the lower part of the arm, the side facing down. Most of the textile fragments are found on the side of the bracelet closest to the body. This repartition of textile suggests more a garment than a shroud. A shroud would have

[35] See Analysis and observations appendix, SEM, Bracelet, p. 181.

covered the uppermost part of the bracelet, or the side of the bracelet facing outwards from the tomb.

The textile can come from a sleeve and/or a garment covering the hip of the deceased, such as a skirt, a dress or a tunic. Based on the stratigraphy, the animal fibre textile could be an underlayer of the clothing or a textile placed beneath the body of the deceased.

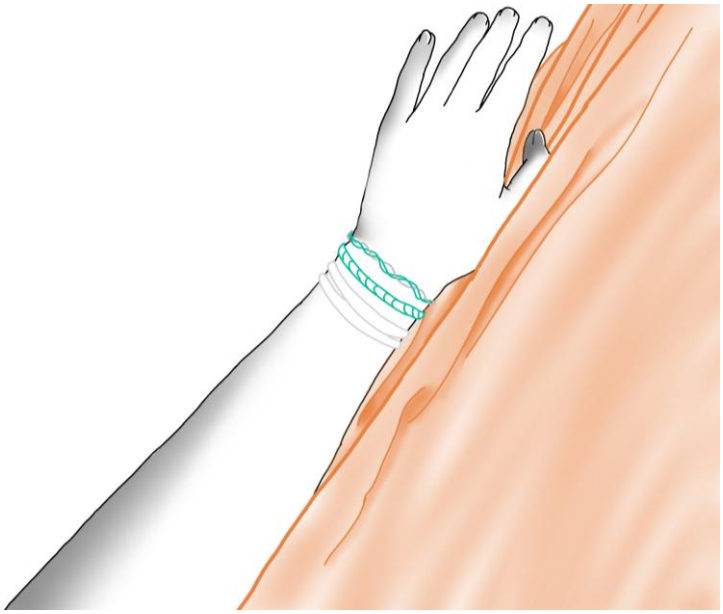


Figure 23: An illustration suggesting a possible scenario to explain the presence of organic remains. Assuming that the deceased is a woman (which has not been confirmed), one could imagine the hem of a dress or skirt resting beneath the left hand, which is wearing bracelets. The colours are not to scale.

The textile remains on the other bracelet were not examined, but they were mapped. Only one layer of textile is preserved on the other ones. We can suggest that this textile layer preserved on the other bracelet is the one that is closer to the metal on bracelet 1. However, this assumption must be verified by further examination.

1.1.3. Conservation proposal and treatments

Conservation decision Bracelet 1

Following the study of the organic remains, it was decided to carry out minimal intervention on the bracelet. Regarding the size of the organic remains associated with it and the aim of the exhibition it will be presented in, it was decided not to remove the corrosion or to proceed to a chemical stabilisation treatment that could damage the organic remains. The bracelet does not require a pristine surface, and the form of the bracelet is already visible without

removal of corrosion. Especially as the corrosion on the part beneath the fragments makes it easy to position them in place. Furthermore, the corrosion of the iron third wire is the only evidence of its presence and removing it would erase this information. On the other hand, the mineralised organic fragments are dissociated and must be put back in place to avoid losing them and so that they recover their original context.

Treatment Bracelet 1

Traces of adhering soil were removed from the organic remains in the areas that could withstand this mechanical stress. Some hard-to-reach areas within the folds of the fabric or between the fibres of the threads could not be cleared. This initial cleaning stage aims to visually prepare the organic remains for study. Soil deposits are removed using an entomologist's needle attached to a wooden stick for a better grip, and a fine, slightly stiff brush to remove loosely adhering soil and powdery corrosion products covering the mineralised organic remains. Soil that is too firmly adhered is moistened with a 50/50% (w/w) mixture of ethanol and demineralised water. The amount of solution on the brush is reduced using absorbent paper if necessary. The aim is to moisten only the soil. Care must be taken to avoid organic remains and metal, which may be sensitive to the drying effects of ethanol or the moisture effect of water. If the textile is well-preserved, it is possible that a large proportion of the fibres are still organic and may react to the solution drying out or being washed out of remaining dyes.

Some fragments of the mineralised textiles were loose and at risk of falling off. These fragile parts were stabilised using Paraloid®B72[36] resin in acetone. The adhesive is applied in a relatively thick consistency, i.e. with little solvent, to prevent it from soaking into the material (Vinçotte et al, 2019, p.2) and to leave much of the surrounding area uncontaminated by the resin. This consolidation is localised. The resin acts as a bond, preferably connecting a fragment of organic remains to the metal object if possible. Bonding is therefore more stable and more reversible on the metal object than on a porous surface.

The iron bracelet that runs between the hook and the loop is broken and no longer provides support for bracelet 1. When it is handled, these parts tend to move relative to one another

[36] Paraloid® B72 is a copolymer of ethyl methacrylate (EMA) and methyl acrylate (MA) with a ratio of 70/30 (Vincotte at al, 2019, p.1). Paraloid®B72 will be noted P-B72 in the following parts.

under their own weight and cause mechanical tension in bracelet 1. A P-B72 adhesive bridge, mixed with Aérosil fumed silica to prevent shrinkage and ensure a more stable bond, was applied to repair the break and stabilise the assembly. It was through-coloured with ochre pigment and black iron oxide pigment.

Corrosion was removed within a limited area of the metal wires to be observed. The small section where the corrosion has been removed reveals that the wires are not perfectly round. Other than that, their surface seems to be smooth and undecorated.

We decided to leave the remaining corrosion in place for several reasons:

- The risk of causing mechanical damage to the textile remains.
  The large area covered by the mineralised textiles makes handling more difficult, and handling could damage the fragile organic remains. Some of the corrosion serves as a support for the mineralised organic remains, and removing it could cause damage.
- Corrosion is the basis for mineralised textiles.
  This is generally the case, but it is particularly true of the detached fragments that have been returned to their original positions on the bracelet. To minimise the risk of losing the fragments and to present them in context, it was decided to reattach them to their original positions.
- Corrosion is a source of information.
  As seen earlier, the twisted bracelet consisted of three metal wires twisted together, one of which was made of an iron alloy. This wire has almost completely disappeared as a result of galvanic corrosion. The traces of corrosion, which do not always retain their original surface, are the only clues to the presence of this element today. A clue that speaks volumes more than a mere space.

The fragments of mineralised organic remains were glued back on the bracelet using P-B72 resin dissolved in acetone (ca 30% w/w). This was carried out after sampling and analysing the textile layers of these fragments. It is, however, still possible to take samples from areas free of resin. No protective coating was applied.

To ensure the long-term stability of the bracelet, it is recommended to use passive environmental control measures to control the object's environment. The climate in the exhibition gallery is stable. For greater control over climatic conditions, it is advisable to place

a desiccant in the display case (e.g. silica gel) to maintain a relative humidity under 50% if it goes up (Rimmer et al, 2013, p. 10). The showcases must be airtight.

Conservation decision Bracelet 2

There are fewer organic remains on bracelet 2. A textile fragment preserved in iron corrosion is limited to a small area near the loop. The handling is easy and does not put the organic remains at risk. The bracelet is fragmented and needs to be joined back together to avoid losing the part and to restore it to a form closer to the original. Corrosion has obscured the bracelet's morphological features. It has been decided to remove the corrosion to expose the original surface, keeping the organic remains in place and to glue back the fragments together. Because the bracelet will be exhibited, corrosion removal was also decided for aesthetic reasons.

Treatment Bracelet 2

The corrosion was removed using a scalpel and a metal needle. The layer of corrosion was brittle and had poor adhesion. Removing the corrosion led to the parts of the coiled wire becoming loose and fragmented. These fragments were reattached using P-B72 resin at 30% in acetone (w/w), applied with a brush. Parts of the coiled wire that were loose following the removal of the corrosion were stabilised using the same resin. The fragments of the bracelet were reattached using Paralloid®B48N[37] in 30% acetone (w/w) (Fig. 23 – 24). P-B48N was designed for metal coating (Molina et al, 2023, p. 104). P-B48N has a greater adhesive strength than P-B72. Even if it is less flexible, we needed a stronger adhesive for the bracelet given the small bonding surface area (ca 3 mm x 3 mm) and the length of the fragments (Davis et al, 2022, pp. 358 – 359). It is also usually used for glueing by the institution. A coating was applied on the surface, avoiding the textile remains. Corrosion removal and broken parts revealed that there is still metal in the core of the bracelet. Because no chemical treatment of stabilisation was carried out, the metal is still sensitive to potential pollutants (like chlorides). A protective coating was applied as a protective coating to isolate the metal surface from the environment and reduce the risk of further corrosion. P-B72 was used at 10% (w/w) in acetone. The solution was ready to use as it is currently being used by the institution. A bond

[37] Paraloid®B48N is a methyl methacrylate–butylmethacrylate copolymer (Molina et al, 2023, p. 104). Paraloid®B48N will be noted P-B48N in the following parts.

was created between the hook and the loop with P-B72 used for glueing to provide final mechanical support.

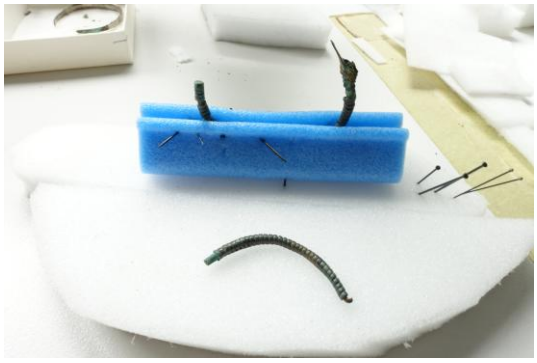


Figure 24: Guidance for the first assembly.

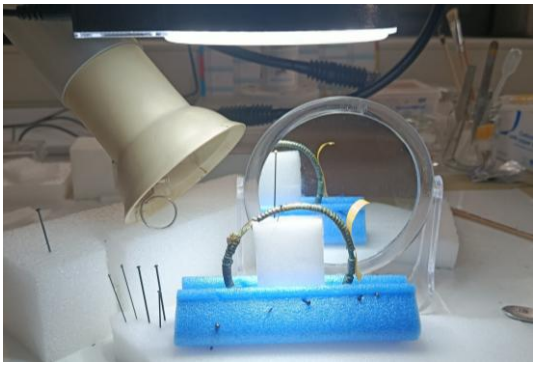


Figure 25: Guidance for the second assembly one week after the first to ensure a strong basis.

Conservation decision Bracelet 3 and 4

The organic materials are restricted to a small area on both bracelets. Because the bracelets will be exhibited, corrosion removal was mostly decided for aesthetic reasons. The use of silver is also a sign of wealth and adds cultural information about the deceased. This cultural information is to be presented to the public.

Treatment Bracelet 3 and 4

Corrosion was removed with the same technique as for bracelet 2. The outer green layer of corrosion was easy to remove. Unfortunately, the underlying cuprite layer of corrosion is very firmly adherent, hard and difficult to remove without risking damage to the surface. One of the difficulties lay in the fact that the layers of corrosion on the copper were much harder than the underlying metal. Particularly hard layers of corrosion were softened by applying Titriplex® EDTA (ethylenediaminetetraacetic acid), a copper-complexing agent, diluted to 3.7% in demineralised water incorporated into a 6% (w/w) concentrated Klucel G gel (a hydroxypropylcellulose). The gel (Fig. 25) was used to avoid damaging textile remains by avoiding bath and minimising the spread of solution. Mechanical removal and chemical softening were alternated.



Figure 26: Removal of the gel with a cotton stick. The gel is blue due to the copper ions in it.

The mineralised organic remains are, however, more extensive on bracelet 4. Their presence made handling more difficult, and additional time would have been required to remove the surrounding corrosion without damaging the organic remains. Furthermore, the gel acts very slowly on cuprite, as this corrosion product is less soluble than most other copper corrosion products. Consequently, due to the lack of time, the removal of the corrosion could not be completed on both bracelets. The corrosion of bracelet 3 was almost completely removed.

For silver, there is a risk of tarnishing due to sulphides. Because the air quality is not known in the museum and it is in a city, the cleared surfaces must be protected against pollutants. The bracelets were coated with the same technique as for bracelet 2 on the exposed areas. It is recommended to place pollutant absorbers, i.e. activated charcoal and silica gel in the display case to get rid of pollutants and maintain a relative humidity of around 50%. As it is a reactive metal, passive environmental control is required in the showcase. For example, they can be placed under a cover with holes, or beneath the support blocks for the bracelets.

1.1.4. Discussion

The restoration of bracelets 1 and 2 has yielded satisfactory results. The conservation approach prioritised the preservation of organic remains on the objects without compromising the metal artefacts. The educational narrative surrounding these objects must be tailored to the public to explain the presence of corrosion and deposits of mineralised organic matter, which they may be less familiar with. The restoration of bracelets 3 and 4 could have benefited from more time. However, the results do not jeopardise the stability and long-term preservation of the metal objects. The care taken with the textile remains, which have not yet been examined, will allow for future examination without the risk of contamination by conservation products.

We decided to show the nematodes in the organic mapping. It shows a part of taphonomical history that explains the conservation or non-conservation of matter. It gives actual information about the grave's environment and the decay of organic matter. It would be an opportunity to consult an entomologist in order to gain a better understanding of the degradation processes.

As it was decided to consolidate the fragile textile fragments on bracelet 1, the question regarding the impact of applying and removing P-B72 resin arose. The application of a consolidating resin may also be considered during chemical stabilisation treatment to remove chlorides from iron objects, for example. To assess this, three fibre fragments were prepared

on an SEM holder. The aim was to compare, against a control sample, the state of preservation before and after the application of P-B72. It appears that their one none or little impact on the fibres. The fibre was in a very good preservation state and was preserved by positive mineralisation. It may give different results with more damaged fibres and other mineralisation types. The impact of only the solvent was not observable. The bigger impact was the handling between the bath of acetone and the documentation. Nonetheless, the coated fibre was well protected from physical alterations before resin removal. This topic warrants further investigation and additional analytical work as the protection of fragile remains is a conservation challenge.

6.2. Case study 2: the inkwell (2026/5944)

1.1.5. Description

The inkwell consists of a jar and a lid (Fig 26 – 27, p. 56). It was placed as a grave good in grave no 1 (find 117). It was situated near the right shoulder, 5 cm from the skull[38]. The presence of the inkwell seems to indicate the individual's status, suggesting that the person was literate. From a scientific value point of view, based on anthropological and geographical evidence, the presence of an inkwell provides insights into the skills of the buried individual and their social circle (Luginbühl 2022, p.147). It is unusual for this region, especially since the individuals buried in this cemetery were civilians. There is no archaeological evidence to suggest an administrative or military role that would explain the presence of an inkwell[39]. Roman graves containing such items have been found north of the Alps from the 1st century AD onwards (Luginbühl 2022, p.150).

Ancient and archaeological sources provide us with a better understanding of the writing tools used in Roman antiquity. The practice spread throughout the empire from Italy. Ink was used to write on imported papyrus and, more rarely, on parchment. This method of writing offered an alternative to the more commonly used wax tablets, on which writing was done using spatulas and special styluses (Oliveira et al, 2024, p. 2; Luginbühl, 2022, p. 147). Other styluses, made of wood, reeds, bone or goose quills, and brushes were tools used to apply

[38] From the excavation drawing, 1998, non published.
[39] Personal communication with Dr. Bernd Steidl, 01.04.2026.

ink. They are less commonly found in archaeological contexts as they were made from perishable materials. Tools for writing with ink are found less frequently in funerary contexts than equipment for writing on wax, but the two may be found together. There is no particular distinction based on gender or age, as these types of objects have been found as grave goods in the tombs of women, men and children alike. But the writing equipment in graves often testifies to the wealth of the richer parts of society, especially women (Luginbühl, 2022, p.152). Such finds are more commonly made near an urban centre or a military settlement. Until today, no such finds are known from the surrounding area of Feldkirchen[40]. It is possible that such a tool was originally in the grave alongside the inkwell but was not lying close enough to be preserved by the corroding metal object.



Figure 27: The inkwell. A big crack is visible.



Figure 28: Upper face of the lid.

1.1.6. Organic material

Several organic residues were identified associated with the inkwell, including white (and some green) mineralised organic material located on the external surface of the jar, black material found inside the jar, filaments caught in the copper corrosion of the external surface of the lid and two white fragments of mineralised organic material difficult to identify on the lid.

The white material is made of 1 to 4 preserved layers and has been identified as wood or tree bast (or just bast fibre?) preserved by lead and copper corrosion products. As it was found all around the surface of the jar, it may be interpreted as a matter that covered the metal entirely. Even if the layers (at least 4 layers) seem to be placed on the surface perpendicular to the previous one and recall a weaving or basketry type of work, nothing like a weaving pattern is

[40] Personal communication with Dr. Bernd Steidl, 01.04.2026.

visible. None of the layers seems to go under or on the next one. Either these parts are not visible anymore, or, if this was basketry, the technique used makes it look like that.

The black material inside the jar is most likely the residue of an ancient ink. The dark colour of the inside really stands out from the soil and must be linked to organic remains. The black material is composed of a powdery substance adhering to the internal surface of the jar and clusters of black material that were found loose inside it. Some of these clusters are made of a black compact powder, and others seem to have a botanical morphology (roots or fungi?). The ink's composition was investigated with XRF, SEM-EDS and FTIR analyses. A significant amount of iron compared to the amount found on the rest of the object was detected, which could suggest an iron-gall-based ink. Some grains with high iron content (up to ca 50%) were found in samples from the black powder thanks to SEM-EDS. However, the FTIR did not show any "iron gall ink, or gallic acid or ellagic acid, respectively", but some goethite and the typical polycyclic aromatic hydrocarbons from soot[41]. Even if the lid was soldered to the jar, they were still found in place but disconnected. Soil contamination could explain the presence of iron. Further analysis will be needed to determine whether the appearance of rich-iron soil is like our images. The soot is a component of a typical recipe for ancient ink; the soot is mixed with a binder. For more information, more in-depth analysis must be carried out (e.g. GC-MS, Gas chromatography–mass spectrometry analysis).

The filaments caught in the copper corrosion of the external layer of the lid have been identified as fungi (mycelium?). The remaining organic fragments are difficult to understand.

The inkwell was most likely decorated or placed in a covering made of bast fibres (or wood). At last, there was enough organic material for fungi to grow before the copper corroded (or at the same time). And the inkwell was placed in the grave with still ink inside. This raises the question of whether there was a stopper made of organic material sealing the lid, which has since disappeared. One of the ink compounds is soot.

[41] Information received by e-mail.

1.1.7. Conservation proposal and treatment

Because of the fragility of the inkwell and the fact that we want to keep the ink in the archaeological context and avoid contamination for further analysis; because the original surface is badly preserved, and corrosion removal treatment would sacrifice the organic remains, it is proposed not to remove the corrosion. A punctual consolidation without penetration of the resin into the organic remains by using a highly concentrated resin is proposed. It is recommended to consolidate big cracks and avoid further manipulation. Photogrammetry can be done to prevent manipulation for study.

Treatments carried out was the cleaning of the soil from the object.

1.1.8. Discussion

It was chosen to preserve organic remains over the metal appearance as X-ray didn't show any traces of surface decoration.

This case study demonstrated a difference in preservation between two different metals when applied to the same material. The lead corrosion preserved more voluminous fragments of the organic material but the material is more fragile and less adherent to the object surface. This observation is possible because two metals from the same object corroded at the same time and mineralised the same material (Fig. 28).

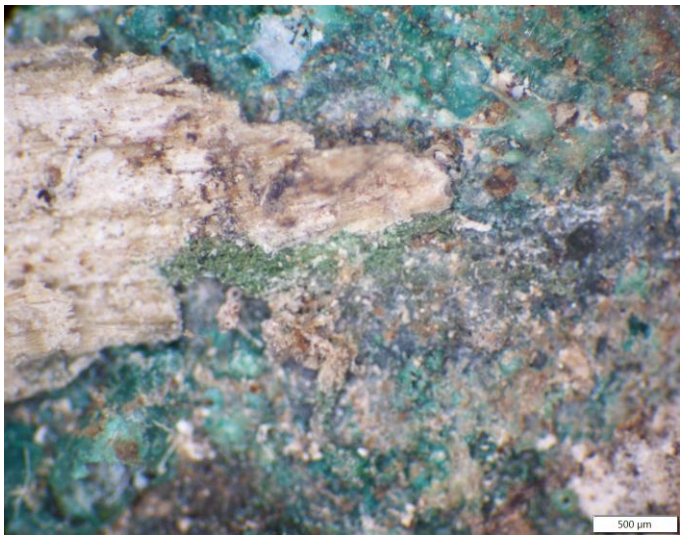


Figure 29: Both copper and lead mineralisation visible on the dame fragment of organic material. The green part is underneath the white.

6.3. Case study 3: the buckle (2026/5943)

1.1.9. Description

The buckle comes from the burial attire of the deceased from grave no. 5 (Discovery Nr. 155). It was excavated near the left thigh of the deceased, with the barb facing upwards and pointing towards the right leg (Ganslmeier, 1998, pp. 1 - 16). Buckles are used to fasten garments or straps. Given its position within the grave, this buckle was therefore worn at the time of burial and was most likely used to fasten a leather belt. It is impossible to say whether it was worn by the individual on a daily basis or whether it was an accessory to the funeral attire used exclusively for the burial.

1.1.10. Organic materials

Mineralised leather remains are visible mainly around the base of the thorn, and a few traces remain around the edge of the frame. Several layers of mineralised textile are visible on the down face of the buckle, near one side of the thorn. Organic remains identified as dark brown plant matter, found in a space in the buckle on the other side of the barb, were preserved as they were mistaken for textile fibres. The quantity of these remains raises questions as to whether they were deliberately placed in the grave or not. It is possible to find botanical

remains, such as bouquets of plants or cushions, which were used to decorate the grave at the time of burial. But it's impossible to draw any conclusions in this case.

Textile remains are preserved by mineralisation on the back of the buckle. They are in a poor state of preservation and only visible by impression of the fibres in the copper corrosion (negative mineralisation). Mineralised leather remains are also on the surface. We can say that a leather belt with a copper buckle was placed in the grave with the deceased, either worn by them or laid upon their body. The deceased was wearing a garment made of animal fibres.

1.1.11. Conservation proposal and treatment

The object is stable in appropriate climate conditions. It is not an object that is particularly unfamiliar to archaeologists. No surface decoration was detected by X-ray. There is a risk of damaging the mineralised organic remains within the corrosion layer during its removal. The boundaries of the leather are difficult to determine. There is no clear justification for removing the corrosion. It may be possible to investigate this further using GC-MS proteomic analyses to detect the presence of leather, and possibly to identify the species for both leather and textile. It is decided to keep the mineralised organic remains on the object. Fragile areas that are loose due to corrosion and black fibres have to be consolidated by applying P-B72 in acetone in located places.

1.1.12. Discussion

About the mineralisation of animal fibres, negative mineralisation is unusual with copper corrosion products. In this case, the degradation of the fibres occurred more rapidly than the mineralisation.

Conclusion

Conservation practices are evolving with the times. We have entered an era in which mineralised organic remains are being taken into account in an increasingly systematic manner. This is driving progress towards the important scientific knowledge that can be gained through their examination.

What seems to emerge from the literature is the importance of collaboration between professionals from different fields. If the curator is not trained in this area, they must be supported by a specialist in organic materials. Finally, the archaeologist, in consultation with the other professionals, oversees the research and makes the final interpretations. The study of mineralised organic remains depends on this collaboration and suffers if not effective.

The following questions have to be examined when a metal object containing organic remains is studied:

- Archaeologist's needs and questions
- State of preservation of the remains
- Remains size
- Stability of the metallic object
- Time and budget for immediate study
- Enough knowledge or need of a specialist
- Tools availability
- Visual access to the metallic object
- Novelty, rarity and importance of the object

The systematic study of organic remains presents new challenges, such as the much greater amount of time required for their examination. Whilst this is necessary, it means we must adapt by making more targeted decisions about which objects to treat and which to leave untreated. In this study, the results of four months' examination of organic remains on three objects were presented: a bracelet, an inkwell and a belt buckle. Three other bracelets were examined more briefly and would have required additional time to draw more definitive conclusions. However, this study has shown that when organic remains are preserved and

stored under good conditions, it is always possible to extract information from them, even 28 years later. With advances in analytical techniques—such as the use of neutrons and muons for imaging and elemental analysis, or proteomics research—the future of research into the mineralisation of organic remains in an archaeological context looks very promising.

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Deepl.com, Linguee and Grammarly was used for correcting and translating.

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Glossary

Alchemy: a type of chemistry, especially in the Middle Ages, that dealt with trying to find a way to change ordinary metals into gold and with trying to find a medicine that would cure any disease (Cambridge Dictionary).

Birefringent: capable of separating light into two rays when the light travels through a substance (Cambridge Dictionary).

Esoteric: very unusual and understood or liked by only a small number of people, especially those with special knowledge (Cambridge Dictionary).

Pennanular: having the form of a ring with a small break in the circumference (Merriam-Webster).

Prophylactic: preventing disease (Cambridge Dictionary).

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Acronyms and abbreviations

ASM	Archäologische Staatsammlung
BLfD	Bayerisches Landesamt für Denkmalpflege
e.g.	For example
FT-IR	Fourier-transform infrared spectroscopy
MOR	Mineralised organic remains
P-B72 / P-B48N	Paraloid B72 / Paraloid B48N
PLM	Polarised light microscopy
SEM-EDS	Scanning electron microscopy and energy-dispersive X-ray spectroscopy
TS/FS	Thread system / Fadensystem
XRF	X-ray fluorescence

Appendices

Photographic appendix

1.1.13. Bracelets 2026/5943

Bracelet 5943_1



Figure 30: Face of bracelet one facing the arm. Before treatment.



Figure 31: Face of bracelet 1 facing the hand. Before treatment.



Figure 32: Big fragments of mineralised organic remains found dissociated from the bracelets in the storage box. Skin side.



Figure 33: Big fragments of mineralised organic remains found dissociated from the bracelets in the storage box. Textile side.



Figure 34: Mineralised textile fragment on bracelet 1. Sommital point of view. Treatment in process.

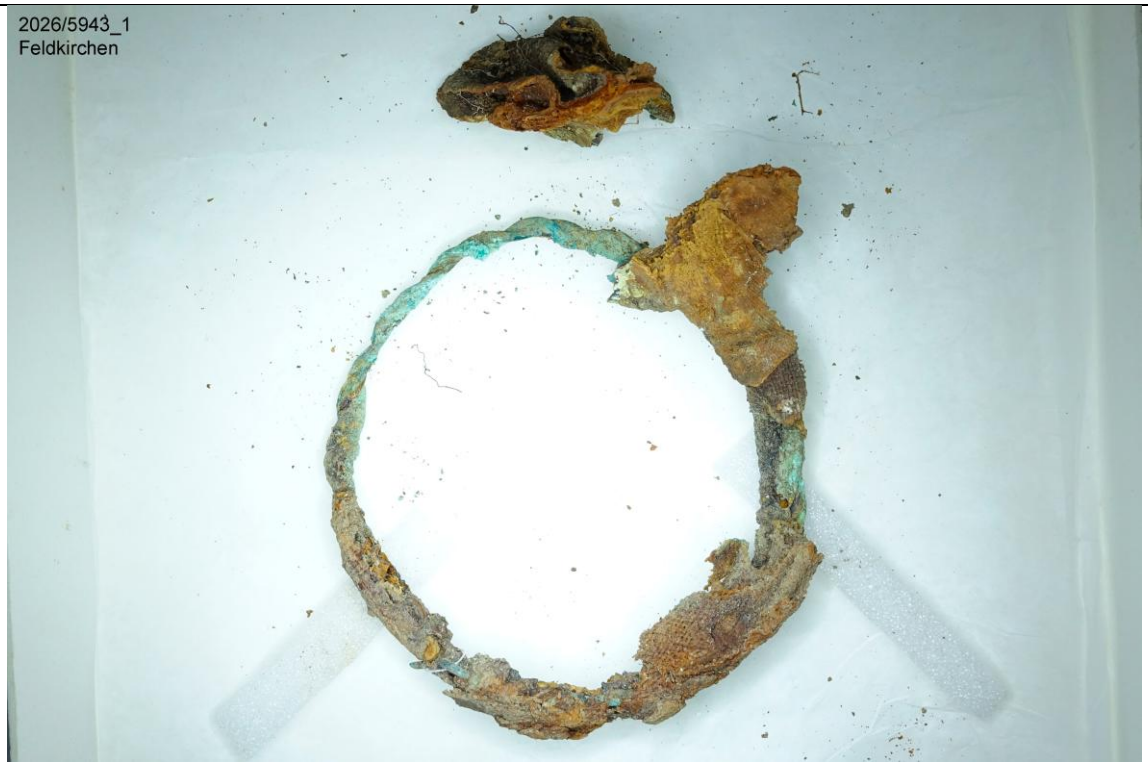


Figure 35: Big fragment of mineralised organic remains from one of them is placed on bracelet 1.



Figure 36: Big fragments of mineralised organic remains placed on bracelet 1. Face 1.



Figure 37: Big fragments of mineralised organic remains placed on bracelet 1. Face 2.



Figure 38: Big fragments of mineralised organic remains placed on bracelet 1. Face 3.



Figure 39: Big fragments of mineralised organic remains placed on bracelet 1. Face 4.



Figure 40: Big fragments of mineralised organic remains placed on bracelet 1. Face 5.



Figure 41: Bracelet 1 after treatment.



Figure 42: Photography of bracelets on site. Unknown author ©BLfD.



Figure 43: X-ray of bracelet 1.

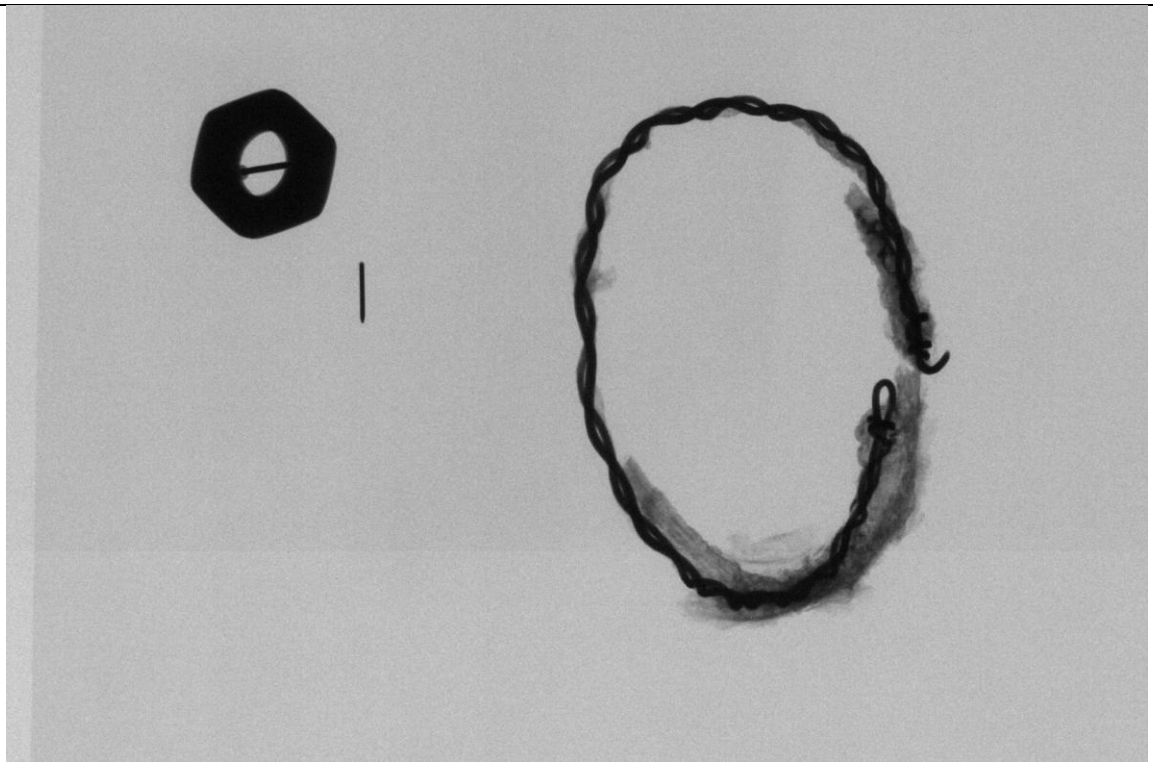


Figure 44: X-ray of bracelet 1. Oblique view.

Bracelet 5943_2



Figure 45: Bracelet 2 before treatment. Face facing the hand.



Figure 46: Bracelet 2 before treatment. Face facing the arm.



Figure 47: Bracelet 2, treatment in process. Face facing the hand.



Figure 48: Bracelet 2, treatment in process. Face facing the arm.

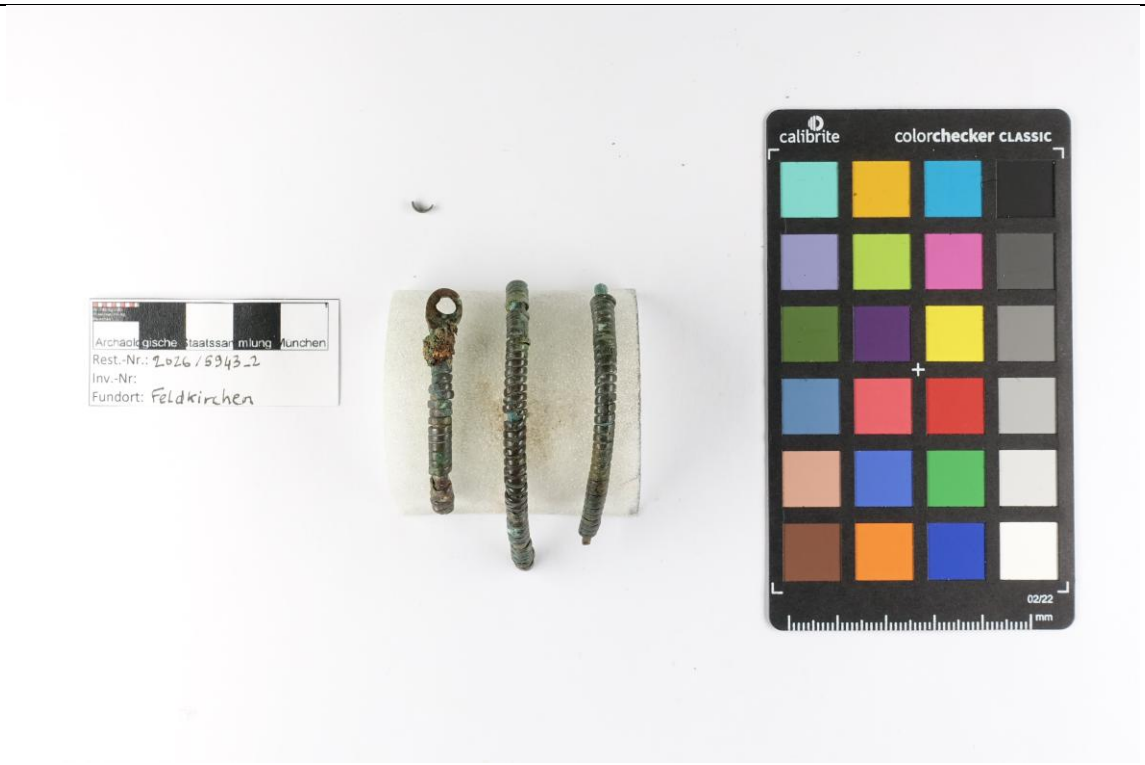


Figure 49: Figure 44: Bracelet 2, treatment in process. External surface.



Figure 50: Bracelet 2, after treatment. Face facing the hand.



Figure 51: Bracelet 2, after treatment. Face facing the arm.



Figure 52: Bracelet 2, after treatment. Oblique view.

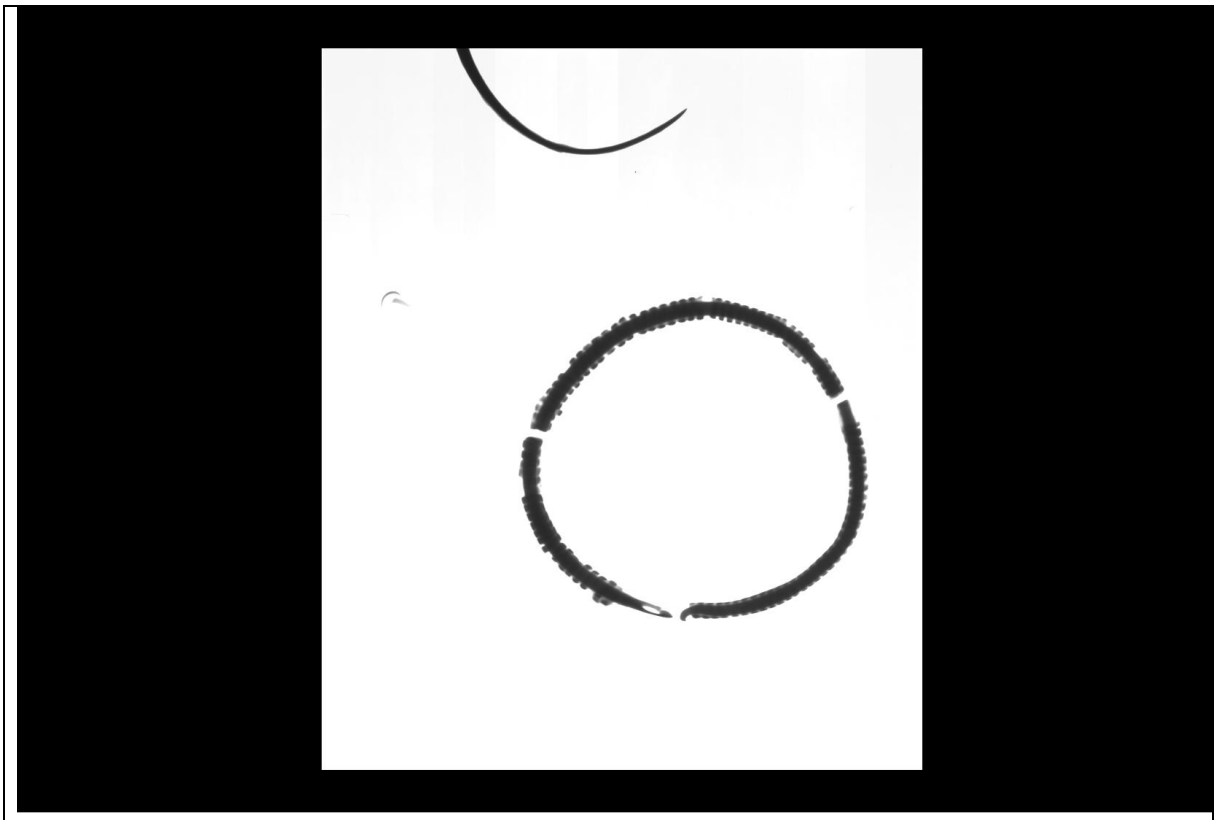


Figure 53: X-ray of bracelet 2.

Bracelet 5943_3



Figure 54: Bracelet 3, before treatment. Face facing the arm.



Figure 55: Bracelet 3, before treatment. Face facing the hand.



Figure 56: Bracelet 3, after treatment. Face facing the hand.



Figure 57: Bracelet 3, after treatment. Face facing the arm.



Figure 58: Bracelet 3, after treatment. Oblique view.

Bracelet 5943_4



Figure 59: Bracelet 4, before treatment. Face facing the hand.



Figure 60: Bracelet 4, before treatment. Face facing the arm.



Figure 61: Bracelet 4, after treatment. Face facing the hand.



Figure 62: Bracelet 4, after treatment. Face facing the arm.



Figure 63: Bracelet 4, after treatment. Oblique view.

1.1.14. Inkwell 2026/5944



Figure 64: Lid of the inkwell. Left: Upper face. Right: inner face. Before treatment.



Figure 65: Face 1 of the inkwell before treatment.



Figure 66: Face 2 of the inkwell before treatment.



Figure 67: Face 3 of the inkwell before treatment.



Figure 68: Face 4 of the inkwell before treatment.



Figure 69: Inside of the inkwell before treatment.



Figure 70: Lid of the inkwell after treatment.



Figure 71: First face of the inkwell after treatment.



Figure 72: Second face of the inkwell after treatment.



Figure 73: Third face of the inkwell after treatment.



Figure 74: Fourth face of the inkwell after treatment.



Figure 75: Inside of the inkwell after treatment.

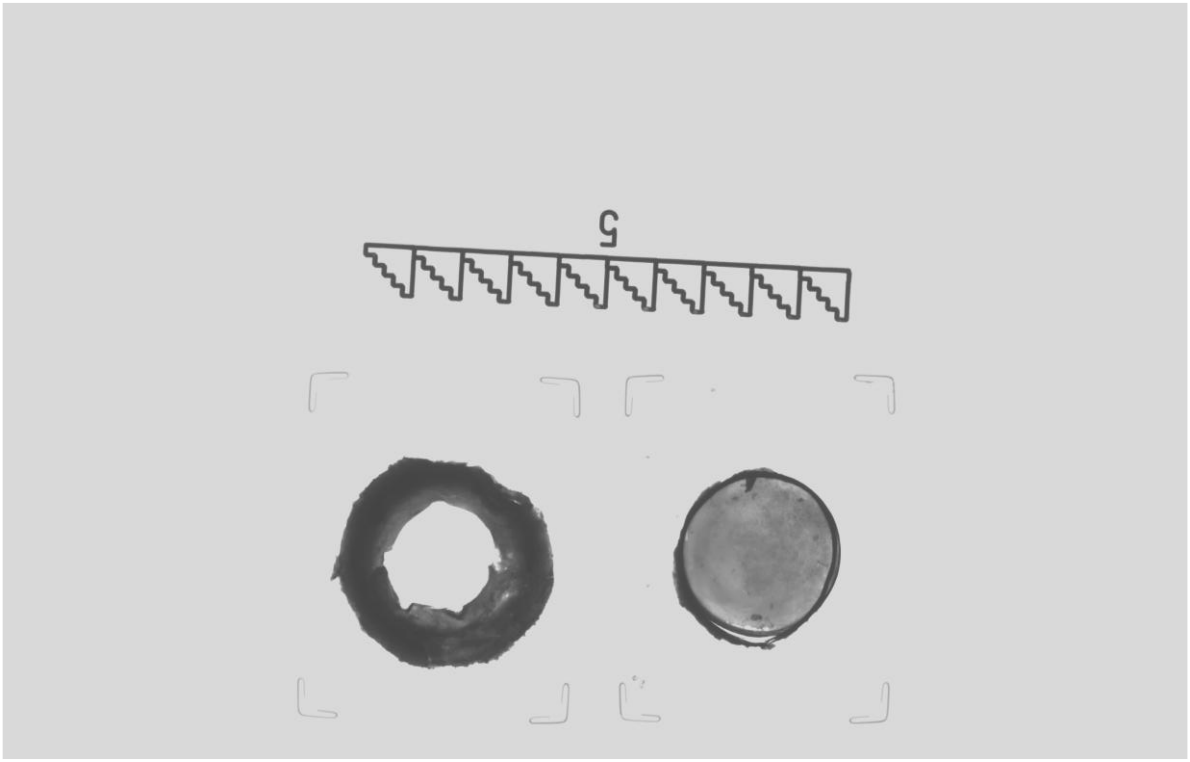


Figure 76: X-ray photography of the inkwell upside down.

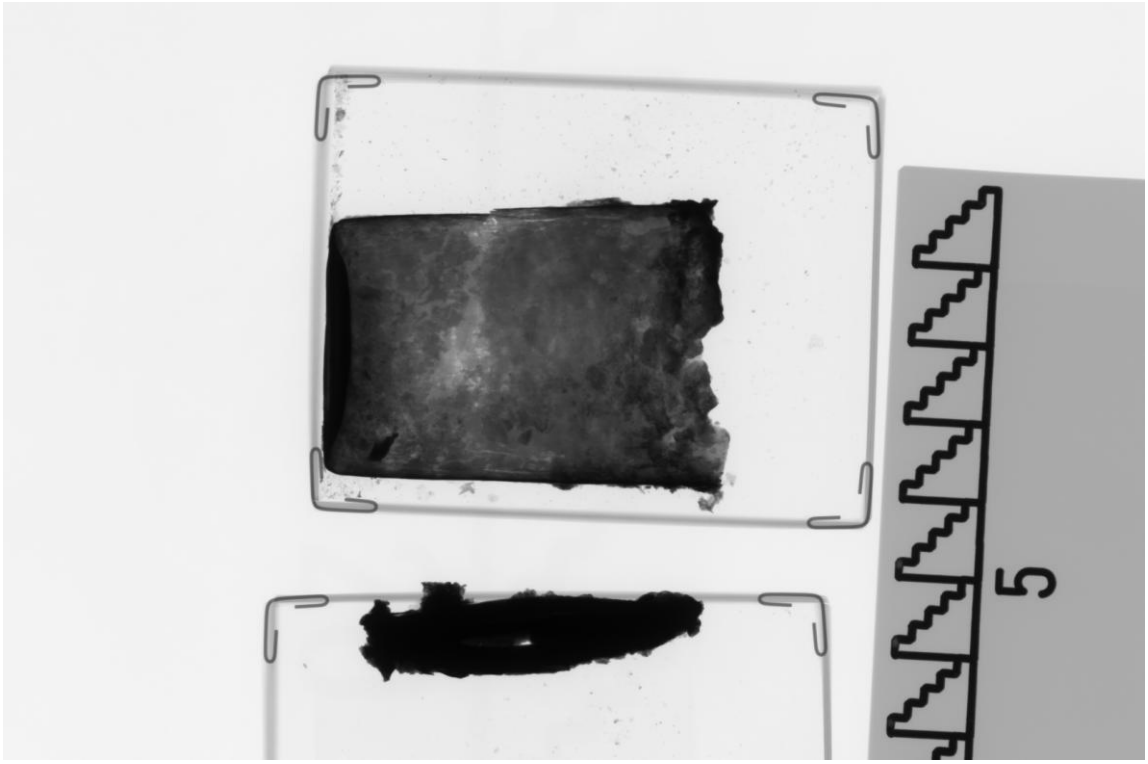


Figure 77: X-ray photography of the inkwell

1.1.15. Buckle 2026/5945



Figure 78: Buckle before treatment. Face.



Figure 79: Buckle before treatment. Back.



Figure 80: Buckle after treatment. Face.



Figure 81: Buckle after treatment. Face.

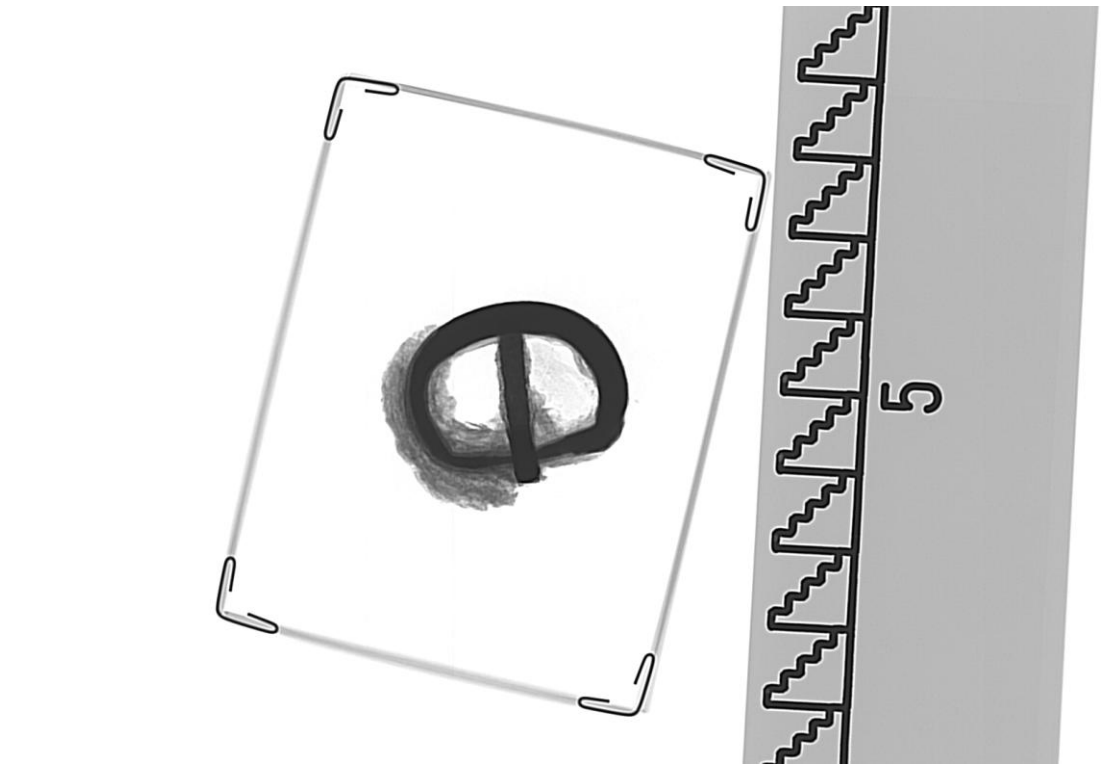


Figure 82: X-ray photography of the buckle. Front.



Figure 83: X-ray photography of the buckle. Mineralisation of the thorn.

Documentation appendix

1.1.16. Bracelets 2026/5943

Condition report

Tableau 2: Identification table of the bracelets.

Name	**Bracelets**
Inventory n°	//
Conservation n°	2026/5943
Excavation n° (Fz)	112
Find n° (Bef)	153
Owner	State of Bavaria
Author	Unknown
Date	4th century AD
Excavation site	St 2082, München-Erding Gde. Ascheim&Feldkirchen Lkr. München
Date of found	1998
Materials	Copper alloy, iron alloy, textile remains, leather remains (?)
Dimensions (lxpxh)	1: 7,3 x 6,2 x 1,4 cm 2: 6,4 x 6,7 x 0,8 cm 3: 5,8 x 5,6 x 0,8 cm 4: 5,5 x 5,2 x 0,7 cm
Weight	1: 9 g 2: 15 g 3: 15 g 4: 14 g



Technological study

Wires can be produced by forging, torsion, and rolling techniques using sheets of metal, which do not require drawplates. With these techniques, some spirally circumferential torsion grooves can be seen on the surface of wires (Gerhards and Willer, 2018, p. 23). Gerhards and Willer identified a new technique of wire making from a previously thin, forged strip of metal sheet rolled lengthwise and gradually drawn out into a wire using a drawplate and drawing pliers (Gerhards and Willer, 2018, p. 24). This technique is illustrated on page 25 of their article.

Bracelet 1 is made of three wires twisted together. One is made of iron alloy, the other two are made of copper alloy. The iron wire is completely gone[42]. A similar example allows us to see how it could have been with all three wires (Fig. 82 - 83). It measures 7,3 by 6,2 cm and 1,4 cm in thickness. An extra fragment of iron, probably from a fifth bracelet, was forged in a circle. Half of it is missing.

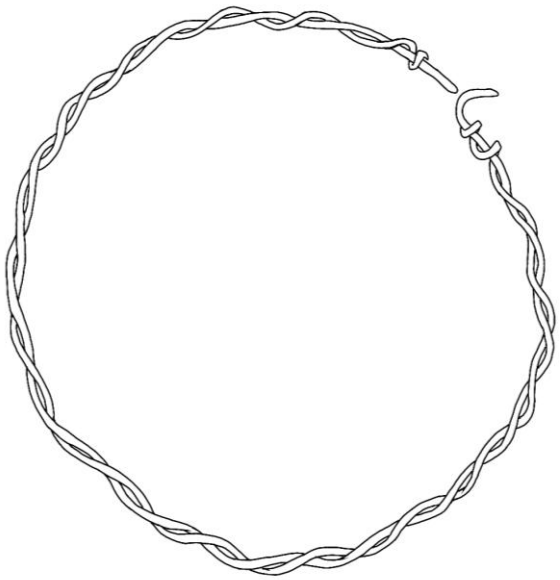


Figure 84: Drawing of the two remaining wires outlined derived from the X-ray.



Figure 85: Restitution proposal of the third iron wire.



Figure 86: Bracelet found in Hadrumète, an ancient Tunisian Roman city in the Louvre collection (Inv. Nr. MND 1479.8 ; Br 4195.1). No date.

[42] See Alterations below.

Bracelet 2 is composed of a bronze wire core with a zinc-rich bronze wire coiled around it[43]. Zinc was cheaper than tin or copper. It also imparts a golden colour to the alloy, which could be used for aesthetic reasons (Craddock, 1978, p. 8). "The tin helps the strength of the alloy, the zinc acts as deoxidant, and the lead improves the casting properties and machinability of the resultant alloy" (Craddock, 1978, p. 14). Since no traces of forging were found on the coiled wire, it is possible that it was cast. In fact, the strand wire measures 1.1 mm in width and 0.3 mm in thickness and is composed of several sections, making it easier to put them on the core wire. The closing mechanism consists of a loop and a hook. The loop was formed by flattening the metal and piercing it. The core wire measures approximately 2.6 mm in thickness.



Figure 87: Bracelet from the Louvre made of a copper alloy core and an iron wire coiled around it. It seems that there is an inlay of another alloy or metal on the coiled wire, but none is mentioned in the description. This interesting association may have had aesthetic reasons. The date and the place of discovery are unknown. (Inv. Nr. Br5213, © 2014 Musée du Louvre / Département des Antiquités grecques, étrusques et romaines)

Bracelets 3 and 4 are made of a silver-copper alloy. They were probably cast then hammered into a C-form.

Alterations and diagnostics

The bracelets had been buried in the ground since the 4th century AD. They were positioned in the upper soil layers, near the surface.

Bracelet 1 is covered by **iron** and **copper corrosion**. The iron corrosion comes from the third wire constitutive of the bracelet and from the fifth **iron bracelet adhering** to its surface. The iron elements seem to be fully corroded. There is no metal left. It is broken

[43] See Analysis and observations appendix, XRF results, p. 159.

between the hook and the loop of bracelet 1. Some dissociated **composite fragments** were found in the storage box. They are composed of mineralised textiles, and skin remains bonded together by iron corrosion. One of them has a fragment of the iron bracelet adhering under it. This helped to place it back on the bracelet.



Figure 88: Fragment of th iron bracelet on a fragment of mineralised organic material.



Figure 89: Location of the fragment in Fig. 86.

The vicinity of the two metals caused the galvanic corrosion of the iron since copper is more noble. Iron corrosion also happens faster. The corrosion caused the iron bracelet to adhere to the twisted bracelet. The iron bracelet could have broken after the excavation, as it is located right on a part subject to stress, as it is where bracelet 1 opens (between the hook and the loop).

Bracelet 2 is **fragmented** into 3 pieces. Three **little fragments** of the strand wire were found in the box. **Corrosion** products cover the surface and hide most of the strand wire. The cross-sections of the wires show almost complete mineralisation along the fracture flanks. But the original surface of the core strand seems to be well preserved. **Iron corrosion** has **deposited** on the surface of bracelet 2 in the form of large blisters with smooth, hard surfaces. In some areas, powdery copper corrosion covers the iron corrosion. The fastening loop is **cracked** and slightly deformed. The strand wire presents a **few cracks** in its width. Bracelet 2 is the least well-preserved of the four. No sign of active corrosion was observed. However, it is impossible to say if its condition changed since the excavation.

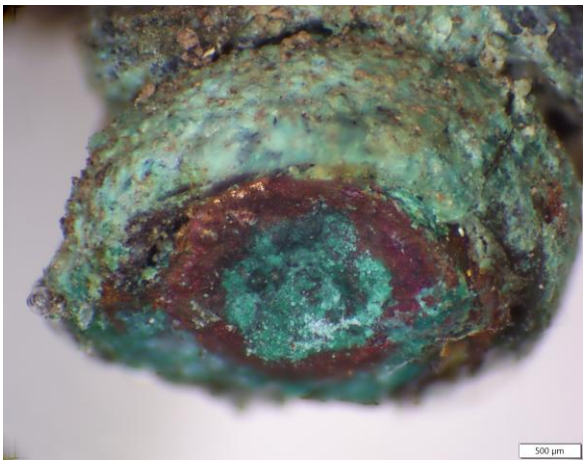


Figure 90: Fracture surface showing mineralisation of the core wire.

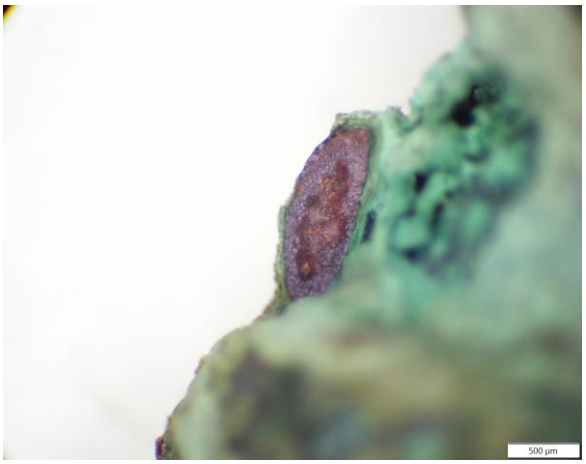


Figure 91: Fracture surface showing the mineralisation of the coiled wire.



Figure 92: Bulk of iron corrosion on the surface of bracelet 2.



Figure 93: Crack in the loop.

Since the bracelet was worn around the wrist, the object probably broke into three pieces upon discovery, at points weakened by corrosion that had developed while it was buried. Corrosion products developed due to the presence of water, oxygen, and other elements found in the soil. Iron corrosion products found on the surface come from bracelet 1. The development of corrosion products, which occupy a greater volume than the metal itself, is associated with the formation of surface cracks on the strand wire.

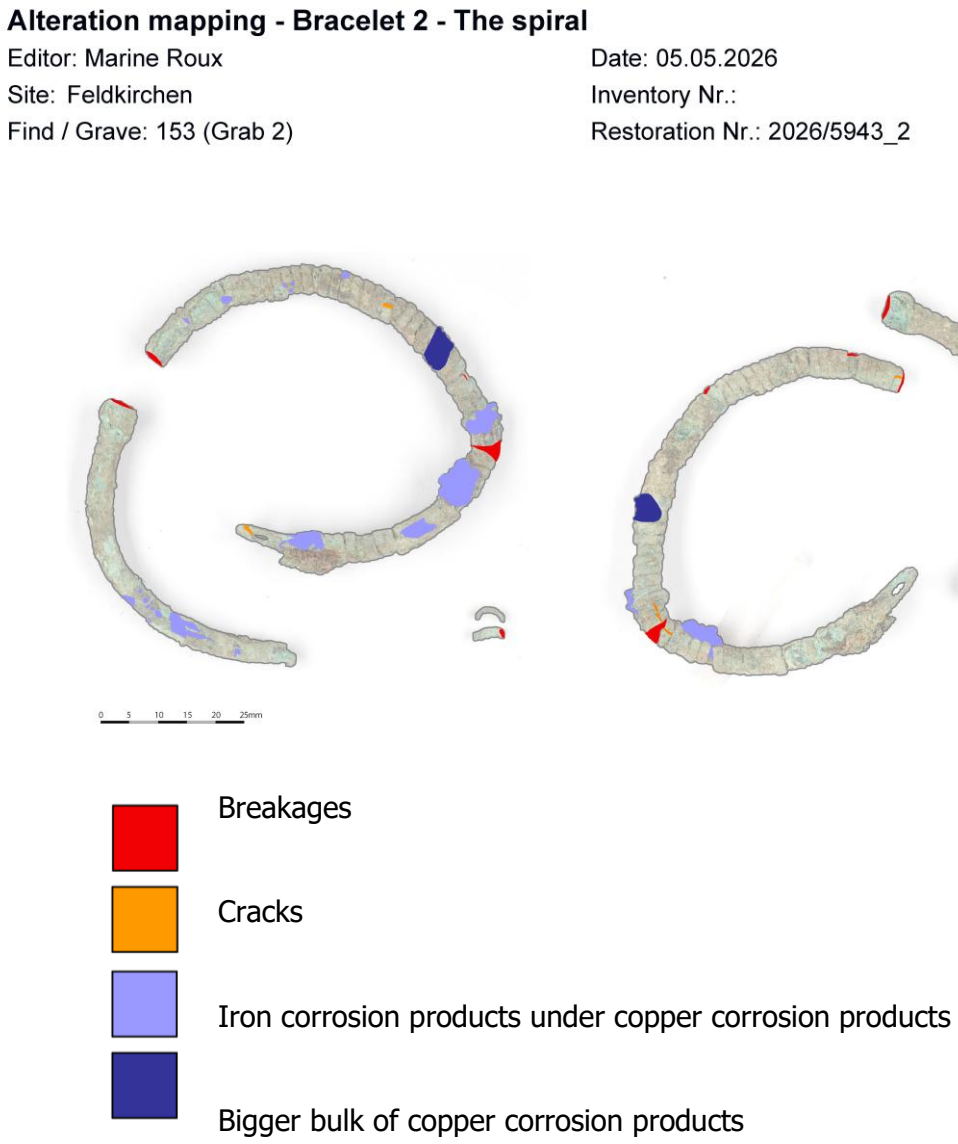


Figure 94: Alteration mapping of bracelet 2.

Bracelets 3 and 4 are covered by **copper corrosion**. Under the bulky green copper corrosion products, there are layers of cuprite and **darker**, almost black, **corrosion products**. The surface is nonetheless well preserved. It is light grey and shiny. Both are in a good structural state. One end of bracelet 3 is **broken** and **missing**. Because their opening are narrower than a thin wrist, they must have been flexible, like a fibula thorn, to be slipped onto the arm. We can say that they **stiffened**.

The burial environment caused the corrosion of the silver alloy. The surface is in a good state of preservation. The broken end was broken after the excavation, as the breakage is not

corroded. Iron corrosion developed faster than copper corrosion. On the other hand, iron deposits covered the bracelet surface before copper corrosion products recovered it.

Pronostics

The main issue for **bracelet 1** is the dissociated fragments of mineralised organic remains that have found their place back on the bracelet. The risk is that we might lose them, even though they provide further information that will help us interpret the presence of the textiles. Otherwise, the corrosion seems stable since there is no metal left in the iron parts. There is no more galvanic corrosion. The adherence of the iron bracelet does not impact the understanding of bracelet 1. The iron corrosion impacts the original form of the iron bracelet.

The fragmentation of **bracelet 2** poses the greatest risk for its conservation because of dissociation risk. Of all the bracelets, its features are the most impacted by corrosion, as it covers the details of the coiled wire.

Bracelets 3 and 4 are stable. The greatest risk is the recurrence of corrosion. Silver is fairly stable in a museum environment, but it is sensitive to airborne pollutants.

Organic documentation

archäologische staatssammlung Fundort **Feldkirchen**: Bearbeiter/in: **Marine Roux**

Rest.Nr **2026/5943_1** Inv.Nr. **Inv.Nr.**

Organikdokumentation zitieren als:
Roux, Marine 2026: Organikdokumentation 2026/5943_1, Feldkirchen. Unpublizierter Bericht (Archäologische Staatssammlung München 2026).

Organikdokumentation

Befundbeschreibung / Einzelfunderfassung

REST.NR:	**2026/5943_1**	INV.NR:	Inv.Nr	
FUNDORT:	Feldkirchen	LANDKREIS:	Bavaria	
LAND:	Germany	SONSTIGE ANM.:	Befund 153, Grab 2	
BEARBEITER/IN:	Marine Roux	START: 05.05.26	ENDE: 10.07.26	
OBJEKT(E):	Bracelet	ZEITSTELLUNG:	4th century AD	

*(Bitte nicht vergessen, vor dem Speichern bzw. Drucken den **Dokumentenkopf** und die **Zitiervorlage** auszufüllen.)*

MATERIAL-ANGABEN:	Copper alloy, iron alloy, preserved organic material: textile, skin (?) + two associated fragments of mineralised organic materials with iron fragments	GEWICHT:	9 g
MAßE (*Länge, Breite, Höhe, Durchmesser*):	7,3 x 6,2 x 1,4 cm Fragment 1: 3,5 x 3,2 x 1,2 cm Fragment 2: 4,1 x 3 x 2 cm Their location on the object is known (5945_1_Feldkirchen_ZZ_6-20). They are joining.		
LAGE IN FUND-ZUSAMMENHANG:	On the left hand of the deceased, along with all the other bracelets.	AUSRICHTUNG:	None
SCHAUSEITE:	nach oben It is difficult to say, the position in the polypropylene box and the photography taken on site seem different. The photography is preferred.		

DOKUMENTATION:	☑ Fotos ☑ Röntgen ☑ Mikroskop ☐ Sonstiges
DOKU-ORDNER:	O:\WERK\BERICHTE\FOTODOKUMENTATION\5901-6000\5943_Feldkirchen#

Kurzbeschreibung und Zusammenfassung der Auswertung:

We can say that the deceased wore a garment made of a bast-fibre tabby-weave textile. An animal-hair textile made of simple threads and plied yarn composed either a layer of the garment or a funerary furniture. These textiles, along with skin remains, were preserved by the iron corrosion provided by an iron bracelet now adhering to bracelet 1.

Seite **1** von **15**

*Zum Erweitern von Tabellen: Bitte komplette Zeile von links außerhalb der Tabelle **markieren, kopieren** und mit **Rechtsklick** **„Zeilen einfügen“***

archäologische staatssammlung Fundort **Feldkirchen:** Bearbeiter/in: **Marine Roux**

Rest.Nr **2026/5943_1** Inv.Nr. **Inv.Nr.**

Beschreibung der organischen Befunde

MATERIALART *(Textil / Leder / Pflanzliche Reste (B) / Holz / Federn (Fd) / Fellhaare (Fh) / Knochen (K) / Horn (Hn) / Substanz bzw. nicht bestimmbare Schicht) / Maße / Lage am Objekt / Zustand usw.:* → „Big fragment" is two fragments joining together and going on the bracelet (5943_1_Feldkirchen_VZ_03; 5943_1_Feldkirchen_ZZ_16).	
S 1	S1 is a very thin, bright orange layer (< 0,05 mm) (M02; M05) of organic material situated on the concave face of the big fragments linked to the bracelet. This layer is not on the bracelet but is only visible on the fragments associated with it. The surface is heterogeneous. It's partially damaged as the surface is abraded and sometimes hollowed, leaving the fabric underneath showing (M05g). Also, the surface appears to bear an imprint as it has a regular texture alternating between aligned depressions and ridges (M02a). And finally, a part of this layer shows folds looking like wrinkles (M02b-f).
T 1	T1 is a layer of dark reddish-brown textile next to S1. This textile is many times folded and is touching the metal (iron fragment and copper wires). Due to aspect similarities and its position on the metal, we can associate this layer on the fragment with the one on the armband. It is very likely the same layer of fabric because of its visual similarities. It is mostly preserved by positive mineralisation, and it still retains well-preserved organic matter.
T 2	T2 is a textile with a closer weave than T1 but with similar-width threads (0,4 – 0,6 mm). It has some folds on the fragments, but none on the bracelet. It is preserved by negative mineralisation. In some areas, the inner part of the thread systems is visible because one of the external surfaces was broken. The corrosion is hard and shiny, dark orange on the outer surface and powdery bright orange inside the layer (M06h-l to compare). On the bracelet, T2 is partially covered by a similar layer of textile. The outer layer is very degraded. It is impossible to say if they come from the same textile (See mapping T1/T2 and S3).
T 3	T3 is located in very restricted areas on T2, only on the big fragment (M06e and j).
T 4	S2 is likely a very degraded textile whose preservation state enables linking this layer with the other textile layers. S2 is on the bracelet only. These fragments are the furthest from the metal.
S 3	S3 are nematodes. There are looking like fibres that are not organised but have a sort of fluidity. It might have been mistaken for fur. On this bracelet, they are mostly preserved in iron corrosion.

*(Die Nummerierung erfolgt von **innen nach außen** sowie **Schau- zu Rückseite** bzw. im Boden **oben zu unten** liegender Seite.)*

*Zum Erweitern von Tabellen: Bitte komplette Zeile von links außerhalb der Tabelle **markieren**, **kopieren** und mit **Rechtsklick** **„Zeilen einfügen"***

archäologische staatssammlung Fundort **Feldkirchen**: Bearbeiter/in: **Marine Roux**

Rest.Nr **2026/5943_1** Inv.Nr. **Inv.Nr.**

Textildokumentation

Textilnummer: T1

Lage am Objekt:

This layer of textile is located near the metal. It covers ca 10 cm of the bracelet. On the big fragment, the size of the fragment is difficult to measure because it is placed between the skin layer (S1) and a second layer of textile (T2) and has many folds.

Textilbeschreibung:

The textile is in a good state of preservation and goes from a positive mineralisation to almost no mineralisation. In the folded areas, where it is difficult to tell apart T1 and T2, the textile that looks like T1 is preserved by negative mineralisation (5943_1_Feldkirchen_M06c). It is a tabby weave. The weaving is a little bit open. FS1 is threads running parallel to the bracelet. The threads of FS2 seem to be further apart than those of FS1 (M02e).

On the bracelet, T1 is a bit stretch in diagonal (M01a). FS1 has threads running perpendicular to the bracelet.

FS1 and FS2 of the fragment and of the bracelet thread systems are not joining. However, if the systems were to match, this configuration would be the most likely. The fragment is positioned in an opposite part of T1 on the bracelet. The direction of the threads is reversed.

Farbe und Material:

The colour was not examined (06.07.2026). Material: bast fibres (presence of nodes). Distinguishing between plant stem bast fibres (e.g., between linen and hemp) is difficult. The Herzog test was performed on P10. It could be linen.

Größe:

T1 covers approximately 9cm of the length of the bracelet. The fragments of textile are folded. It is difficult to evaluate the proper size of the T1 fragments.

Beziehung zu anderen Textilresten:

Between the bracelet and the fragments.

Identifizierung Kette und Schuss:

No.

Gewebetechnische Details:

On the fragment	**Fadensystem 1** (-Verlauf)	**Fadensystem 2** (-Verlauf)
Garn/Zwirn	z	z
Fadendrehung	--	--
Drehwinkel	Ca 20 - 30°	Ca 20 - 30°
Fadenstärke	Ca 0,3 – 0,4 mm	Ca 0,3 – 0,4 mm

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*Zum Erweitern von Tabellen: Bitte komplette Zeile von links außerhalb der Tabelle **markieren**, **kopieren** und mit **Rechtsklick „Zeilen einfügen“***

archäologische staatssammlung Fundort **Feldkirchen:** Bearbeiter/in: **Marine Roux** Rest.Nr **2026/5943_1** Inv.Nr. **Inv.Nr.**

Gewebedichte (Fäden pro cm)	21 threads/cm (measured on 5,2 mm)	15 threads/cm (Measured on 7,7 mm)

*Calculated on less than a cm.

FS1/2: Stärke (FS1/2; cm) * Dichte (FS1/2) = xx

→ *Abdeckfaktor*: FS1 + FS2 – (FS1 * FS2) = yy
→ Auswertung nach Hammarlund 2004

[*Doppelfäden*: *Gewebedichtewert muss der*

On the bracelet	**Fadensystem 1** (-Verlauf)	**Fadensystem 2** (-Verlauf)
Garn/Zwirn	z	z
Fadendrehung	--	--
Drehwinkel	Ca 15 - 20°	Ca 30°
Fadenstärke	Ca 0,3 – 0.4 mm	Ca 0.3 – 0,35 mm
Gewebedichte (Fäden pro cm)	14 threads/cm (Measured on 6,8 mm)	16 threads/cm (Measured on 6,3 mm)

Abdeckfaktor:

--

Bindungsart:

--

Anmerkungen:

--

Proben *(inkl. Aufbewahrungsort bzw. Trägerart o.ä., falls bereits aufbereitet)*:

5945_P10 (glass slide)

Bilder:

5943_1_Feldkirchen_P10_P-Entnahmestelle / 5943_1_Feldkirchen_P10_REM-Traeger

Oberflächenbesonderheiten, Nähte, Säume, Muster:

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Interpretation (Schlagwort):

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Seite **5** von **15**

*Zum Erweitern von Tabellen: Bitte komplette Zeile von links außerhalb der Tabelle **markieren**, **kopieren** und mit **Rechtsklick** **„Zeilen einfügen“***

archäologische staatssammlung Fundort **Feldkirchen:** Bearbeiter/in: **Marine Roux** Rest.Nr **2026/5943_1** Inv.Nr. **Inv.Nr.**

Textilnummer: T2

Lage am Objekt:

This layer of textile is located between T1 and T3. It covers ca 4,5 cm of the bracelet. On the big fragment, the size of the fragment is difficult to measure because it has many folds.

Textilbeschreibung:

The textile is mostly preserved by negative mineralisation. A hard dark orange corrosion crust covers the fibres, while the inner part is a light orange powdery corrosion (Teil4_M05). This layer of textile tends to split lengthways. The corrosion crust of the external part limits the observation of the fibres. characteristics. We can say that this is a tabby weave. The weaving is tight. FS1 is threads running parallel to the bracelet.

On the bracelet, T2 is the layer on T1. FS1 is threads running perpendicular to the bracelet.

FS1 and FS2 of the fragment and of the bracelet thread systems are not joining. However, if the systems were to match, this configuration would be the most likely. The fragment is positioned in an opposite part of T1 on the bracelet. The direction of the threads is reversed.

Farbe und Material:

The colour was not examined (10.07.2026). Material: bast fibres (presence of nodes). Distinguishing between plant stem bast fibres (e.g., between linen and hemp) is not possible with the applied technique.

Größe:

T2 layer covers 4.5 of the bracelet length. The fragments are approximately 1,5 large. T2 seems thinner than T1, but it is difficult to tell whether it is their original thickness or if it changed because of the preservation process.

Beziehung zu anderen Textilresten:

Between the bracelet and the fragments.

Identifizierung Kette und Schuss:

No.

Gewebetechnische Details:

On the fragment	**Fadensystem 1** (-Verlauf)	**Fadensystem 2** (-Verlauf)
Garn/Zwirn	z	z
Fadendrehung	--	--
Drehwinkel	Ca 30 - 40°	Ca 25 - 35°
Fadenstärke	Ca 0,4 – 0,6 mm	Ca 0,4 – 0,6 mm
Gewebedichte (Fäden pro cm)	16 threads/cm	19 threads/cm

Seite **6** von **15**

*Zum Erweitern von Tabellen: Bitte komplette Zeile von links außerhalb der Tabelle **markieren**, **kopieren** und mit **Rechtsklick „Zeilen einfügen“***

	(measured on 8,4 mm)	

On the bracelet (M10a)	**Fadensystem 1** (-Verlauf)	**Fadensystem 2** (-Verlauf)
Garn/Zwirn	z	z
Fadendrehung	--	--
Drehwinkel	--	--
Fadenstärke	--	--
Gewebedichte (Fäden pro cm)	15 threads/cm (Measured on 0,5 mm)	15 threads/cm (Measured on 0,6 mm)

FS1/2: Stärke (FS1/2; cm) * Dichte (FS1/2) = xx

→ *Abdeckfaktor*: FS1 + FS2 – (FS1 * FS2) = yy
→ Auswertung nach Hammarlund 2004

[*Doppelfäden*: *Gewebedichtewert muss der*

Abdeckfaktor:

--

Bindungsart:

--

Anmerkungen:

--

Proben *(inkl. Aufbewahrungsort bzw. Trägerart o.ä., falls bereits aufbereitet)*:

5945_P11 (SEM-stub)

Bilder:

5943_1_Feldkirchen_P11_P-Entnahmestelle / 5943_1_Feldkirchen_P11_REM-Traeger

Oberflächenbesonderheiten, Nähte, Säume, Muster:

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Interpretation (Schlagwort):

--

*Zum Erweitern von Tabellen: Bitte komplette Zeile von links außerhalb der Tabelle **markieren**, **kopieren** und mit **Rechtsklick** **„Zeilen einfügen“***

archäologische staatssammlung Fundort **Feldkirchen**: Bearbeiter/in: **Marine Roux** Rest.Nr **2026/5943_1** Inv.Nr. **Inv.Nr.**

Textilnummer: T3

Lage am Objekt:

T3 is only visible on the big fragment in two areas. Two little fragments are adhering to T2 on the lower part of the big fragment situated near the bracelet (M06e and j; ZZ_18). One loose fragment that was found in the box joins with one of them (M01).

Textilbeschreibung:

T3 is a tabby-woven textile with S-plied z thread for one system (thread system 1) and simple z thread for the other (thread system 2). They were preserved by negative mineralisation, leaving an imprint of the external surface of the fibre. There are still some very degraded organic fibres present in the corrosion (5943_1_Feldkirchen_P12_REM_015 a; 5943_1_Feldkirchen_P12_REM_019 a).

Farbe und Material:

The colour was not examined (26.02.2026). Material: animal hair. The cross-section of the fibre is round to oval. They measure ca 30 µm (25 – 35 µm) in width. The cuticle has scales arranged in a regular mosaic (Rast-Eicher, 2016, p. 13). The scales are in an intermediate position, broad petals, smooth and distant (Teerink, 2003, p. 7). It could be sheep or goat hairs or any animal presenting a similar hair structure.

Größe:

Adhering fragments to T2: 7,9 x 5,6 mm and 7,1 x 4,2 mm.

Loose Fragment: 7,2 x 4,9 mm (it goes with the bigger one).

Beziehung zu anderen Textilresten:

No relationship with other fragments was found other than on the big fragment. No traces of T3 were found on a bracelet.

Identifizierung Kette und Schuss:

No. (?)

Gewebetechnische Details:

	Fadensystem 1 (TS1) (-Verlauf)	**Fadensystem 2 (TS2)** (-Verlauf)
Garn/Zwirn	z	z
Fadendrehung	S	--
Drehwinkel	Ca 20° (thread) Ca 1-10° (plyed yarn)*	Ca 30°
Fadenstärke	Ca 0,5 – 0,6 mm	Ca 0,3 mm
Gewebedichte (Fäden pro cm)	Ca 21 thread/cm	Ca 10 thread/cm

* Difficult to see, seems plied but with a very low angle torsion.

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*Zum Erweitern von Tabellen: Bitte komplette Zeile von links außerhalb der Tabelle **markieren**, **kopieren** und mit **Rechtsklick „Zeilen einfügen“***

archäologische staatssammlung Fundort **Feldkirchen**: Bearbeiter/in: **Marine Roux** Rest.Nr **2026/5943_1** Inv.Nr. **Inv.Nr.**

Details zu den naturwissenschaftlichen Analysen

Entnommene Proben

PROBENNR.: **P10**	
Beschreibung: FS1 and FS2 of T1layer (closest to the metal). Mineralised textile layer on the big fragment. *Aufbewahrung / Verarbeitung:* Microscope glass slide. Embedding with Meltmount™ 1.662. *Zugehörige Bilder:* 5943_1_Feldkirchen_P10_P-Entnahmestelle / 5943_1_Feldkirchen_M02e *Fragestellung:* Fibre identification. *Ergebnis:* The fibres are still in a good preservation state. The samples for FS1 and FS2 were collected on the big fragment close to each other. Under a polarised light microscope, for both samples, we observed nodes, characteristic of bast fibres (5943_1_Feldkirchen_P10_TS1_PLM04). The Herzog test gave a result only for FS1 (5943_1_Feldkirchen_P10_TS1_PLM01-2). It could be nettle or linen (S-twist bast fibre (Haugan, Holst, 2013, p. 166). There was no result for FS2, probably due to the preservation state of the fibres (5943_1_Feldkirchen_P10_TS2_PLM04-5). ---> FS1 and FS2: Bast fibre. FS1: maybe linen or nettle.	
PROBENSTANDORT (*nach Analyse*):	P-Standort
VORGENOMMENE ANALYSEN: ☐ REM ☐ EDX ☐ RFA ☑ DLM / PLM ☐ Chemische Untersuchung ☐ Sonstiges	
VERWENDETE CHEMIKALIEN:	Chemikalien

*Für jede Probe kompletten Tabellenblock **kopieren** und hintenan **einfügen**.*

PROBENNR.: **P11**
Beschreibung: FS1 and FS2 from the T2 layer. Between T1 and T3. Mineralised textile fragment from the organic material. *Aufbewahrung / Verarbeitung:* SEM-stub. *Zugehörige Bilder:* 5943_1_Feldkirchen_P11_P-Entnahmestelle / 5943_1_Feldkirchen_P11_REM-Traeger *Fragestellung:* The sample for FS1 and FS2 was collected on a broken edge of T2 on the bigger batched organic fragments. In the area, the layer is cleaving in the middle, as this layer is mostly preserved by

*Zum Erweitern von Tabellen: Bitte komplette Zeile von links außerhalb der Tabelle **markieren**, **kopieren** und mit **Rechtsklick „Zeilen einfügen“***

archäologische staatssammlung Fundort **Feldkirchen**: Bearbeiter/in: **Marine Roux** Rest.Nr **2026/5943_1** Inv.Nr. **Inv.Nr.**

negative mineralisation (M06p). The external surface is harder than the fragile and powdery internal part. The sample was collected where FS1 and FS2 are visible by an imprint.
The same results were observed for FS1 and FS2. In cross-section under the SEM (REM), the fibres are mostly polygonal. Their width varies on average around 10 µm and ranges from 9 to 20 µm. Both thread systems have fibres with nodes visible even if the fibres are quite degraded. However, we can't be more precise about the nature of the fibre without further analysis.

---> FS1 and FS2: bast fibres.

Ergebnis:

PROBENSTANDORT (*nach Analyse*):	P-Standort

VORGENOMMENE ANALYSEN:

☑ REM ☐ EDX ☐ RFA ☐ DLM / PLM ☐ Chemische Untersuchung ☐ Sonstiges

VERWENDETE CHEMIKALIEN:	Chemikalien

*Für jede Probe kompletten Tabellenblock **kopieren** und hintenan **einfügen**.*

PROBENNR.: **P12**

Beschreibung: FS1 and FS2 from the T3 layer. On T2 (further from the metal). Mineralised textile fragment from the organic material. On the bigger of the two fragments of T3.

Aufbewahrung / Verarbeitung: SEM-stub.

Zugehörige Bilder: 5943_1_Feldkirchen_P12_P-Entnahmestelle / 5943_1_Feldkirchen_P12_REM-Traeger

Fragestellung: Fibre identification and see if it discriminates between FS1 and FS2 (FS1 is made of a plied yarn of two threads).

Ergebnis: The samples for FS1 and FS2 were collected in a close area. The fragility of the fibre complicated the sampling, that cannot be done without partially crushing them. The same results were observed for FS1 and FS2. Under the SEM (REM), their cross-section varies from round to oval. Their width varies on average around 30 µm and ranges from 25 to 36 µm. Cuticle with scales was visible as an imprint on the corrosion. The cuticles have scales arranged in a regular mosaic (Rast-Eicher, 2016, p. 13). The scales are in an intermediate position, broad petals, smooth and distant (Teerink, 2003, p. 7). The hypothesis remains uncertain, but the animals that most match the observations could be sheep or goat hairs or any animal presenting a similar hair structure.

→ FS1 and FS2: animal hair.

*Zum Erweitern von Tabellen: Bitte komplette Zeile von links außerhalb der Tabelle **markieren**, **kopieren** und mit **Rechtsklick „Zeilen einfügen"***

archäologische staatssammlung Fundort **Feldkirchen**: Bearbeiter/in: **Marine Roux**

Rest.Nr **2026/5943_1** Inv.Nr. **Inv.Nr.**

Auswertung

Skin and textile fragments were identified on the bracelet. The bracelet was made of different alloys for each of the wires used to make its twisted core. An additional iron fragment that seems to be a fifth bracelet adheres to it. Almost all of the preserved organic remains are preserved by iron corrosion products.

Two different types of tabby fabric (T1 and T2) appear to cover a part of the bracelet, comprising approximately six layers. A third one has been identified only on the batched organic fragments found separated from the bracelet that also include T1 and T2. It is also only on these fragments that there are skin remains (S1). T1 and T2 are made with bast fibres (maybe linen). Their proximity and the fact that T1 has many folds could suggest that these two pieces of fabric come from the same textile. T1 seems less tightly woven than T2, but this can occur in handcrafted items or due to uneven tension in the fabric during use. However, the difference in their state of preservation suggests that they are, in fact, two different pieces of fabric. T1, closer to the metal, presents two types of preservation: almost no mineralisation and intact in its organic form and by positive mineralisation. Some fibres are still very flexible. T2, one T1 layer apart from the layer on the bracelet, is preserved mostly by negative mineralisation and is covered by a hard layer of iron corrosion products. T3 is made of animal hair (maybe wool) and is a tabby weaving with a plied-yarn thread system. It is preserved by negative mineralisation. T3 is on T2. On the bracelet, the layer further away from the metal is very degraded (T4). For the fragments, the size of the preserved organic remains is impressive and is and is most likely due to the presence of this iron bracelet.

The loose fragments were placed back on the bracelet thanks to a fragment of the iron bracelet under one of them. We could join a first fragment to the bracelet by finding the broken joint. This helped to precise the stratigraphy. Along with the photograph of the bracelets on site (SW19_Bef153-Gr2_DetAmring-1), the skin position on the bracelet seems to come from the lower part of the arm, the side facing down. Most of the textile fragments are found on the side of the bracelet closest to the body. This repartition of textile suggests more a garment than a shroud. A shroud would have covered the uppermost part of the bracelet, or the side of the bracelet facing outwards from the tomb.

The textile can come from a sleeve and/or a garment covering the hip of the deceased, such as a skirt, a dress or a tunic. The large number of folds supports the idea that larger fragments came from a bigger part of a garment than a sleeve. Whilst textiles made from bast fibres are certainly part of the clothing, it is more difficult to say the same for textiles made from wool. Based on the stratigraphy, T3 could be an underlayer of the clothing or a textile placed beneath the body of the deceased. This could be clarified by a more detailed analysis of the heavily degraded textile remains on the bracelets and by comparing the findings with the clothing practices of the period. Was the wool generally worn as an undergarment or over another garment?

Nematodes (S2) were preserved mostly on the iron bracelet. They were also found in greater numbers on the other bracelet, where they were caught in copper corrosion products.

---> We can say that the deceased wore a garment made of a bast-fibre tabby-weave textile. An animal-hair textile made of simple threads and plied yarn composed either a layer of the garment or a funerary furniture. These textiles, along with skin remains, were preserved by the iron corrosion provided by an iron bracelet now adhering to bracelet 1.

*Zum Erweitern von Tabellen: Bitte komplette Zeile von links außerhalb der Tabelle **markieren**, **kopieren** und mit **Rechtsklick** **„Zeilen einfügen“***

archäologische staatssammlung Fundort Feldkirchen: Bearbeiter/in: Marine Roux Rest.Nr 2026/5943_1 Inv.Nr. Inv.Nr.

The textile remains on the other bracelet were not examined. At least they were mapped. We can suggest that the textile preserved on the other bracelet is T1, as textile remains are mainly preserved as a single layer directly on the metal. However, this assumption must be verified by further examination.

Cited documents:

HAUGAN, E. and HOLST, B., 2013. Determining the fibrillar orientation of bast fibres with polarised light microscopy: the modified Herzog test (red plate test) explained. Journal of Microscopy. Vol. 252, no. 2, pp. 159–168. DOI 10.1111/jmi.12079.

Rast-Eicher, A. (2016). Fibres: Microscopy of Archaeological Textiles and Furs. Archaeolingua.

Teerink, B. J. (1991). Hair of West European mammals: Atlas and Identification Key. Cambridge University Press.

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*Zum Erweitern von Tabellen: Bitte komplette Zeile von links außerhalb der Tabelle **markieren, kopieren** und mit **Rechtsklick** **„Zeilen einfügen“***

Figure 95: Organic documentation standardised sheet of bracelet 1. Some pages are not shown: page 3, the organic mapping presented next, and pages 3, 9, 12 and 13, documentation specific to the institution or specifications not relevant here.

Organic mapping

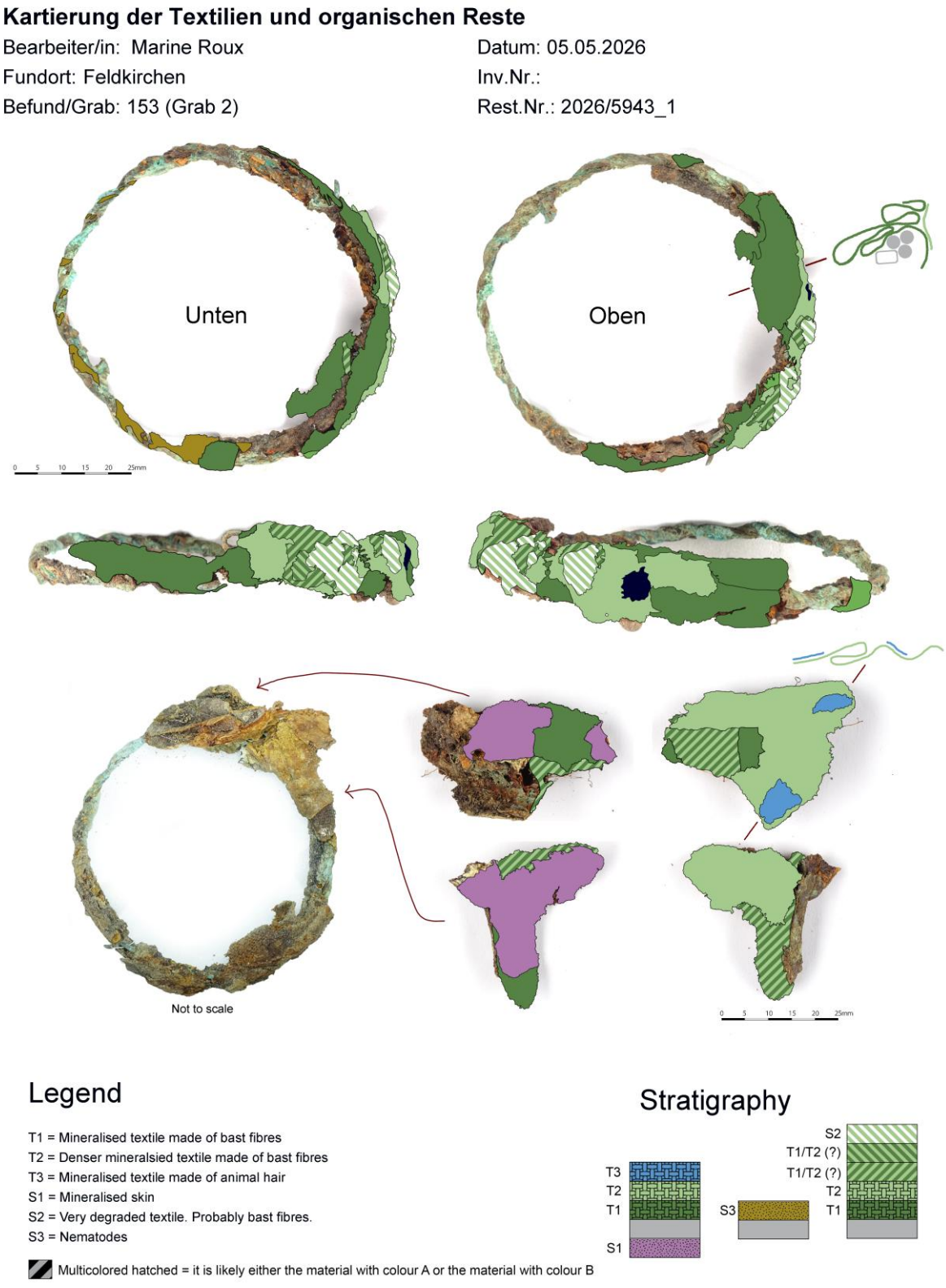


Figure 96: Organic mapping of bracelet 1.

Handling recommendations

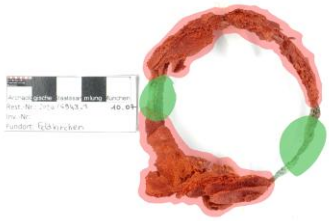


Figure 97: Handling of bracelet 1.

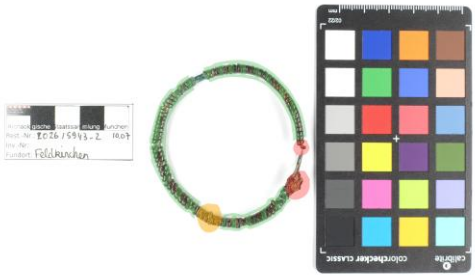


Figure 98: Handling of bracelet 2.

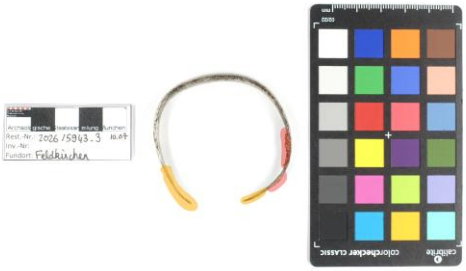


Figure 99: Handling of bracelet 3.

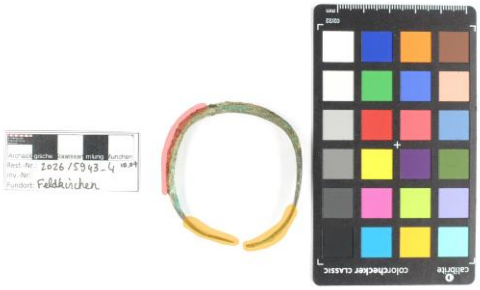


Figure 100: Handling of bracelet 3.

These drawings aim to indicate safe zones to handle the bracelet, avoiding the organic remains. The safest zone to handle the object is shown in green or without colour. For bracelet 2, the green striped area indicates to be careful about parts that stand out and can be fragile, like the one shown in orange. For bracelets 3 and 4, the ends are to be avoided as they are thinner and more fragile. The red zone is the location of the organic remains.

1.1.17. Inkwell 2026/5944

Condition report

Tableau 3: Identification table of thee inkwell.

Name	**Inkwell**
Inventory n°	//
Restoration n°	2026/5944
Excavation n° (Fz)	52
Feature n° (Bef)	117
Owner	State of Bavaria
Date	4th century AD, Late Roman
Excavation site	St 2082, München-Erding Gde. Ascheim&Feldkirchen Lkr. München
Date of found	1998
Materials	Copper alloy, organic remains, probably ink
Dimensions (lxpxh)	Jar: 3,7 x 3,2 x 5,2 cm Lid: 4,8 x 5 x 1,3 cm
Weight	Lid: 13 g Jar: 21 g



Technological study

The inkwell was made from a copper-tin-lead alloy (a ternary Cu-Sn-Pb alloy)[44]. Bronze (or, more likely, a copper alloy) was the most commonly used material for making inkwells in the 4th century AD (Luginbühl 2022, p. 150). To obtain such a thin result, the jar was hammered from a sheet of copper alloy (Fig. 99 – 105). There is no overlapping matter visible on the X-ray radiography[45]. Here are some illustrations showing how it could have been made.

[44] See Analysis and observations appendix, XRF results, p. 166.
[45] See Photographic appendix, p. 93.

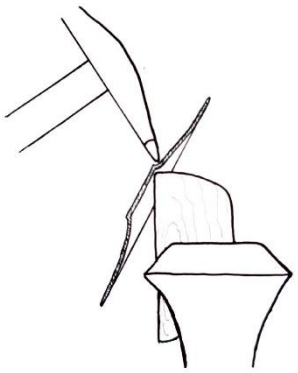


Figure 101: Setting the bottom

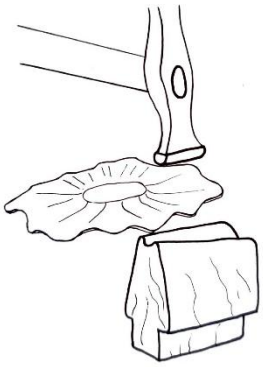


Figure 102: Folding the folds

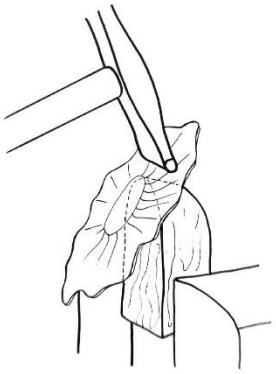


Figure 103: Drawing in the folds

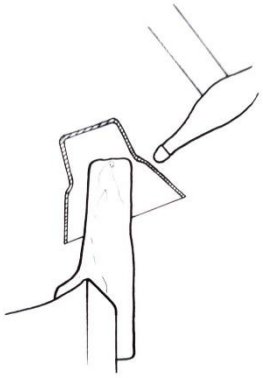


Figure 104: Upsetting the cup wall with the fin hammer

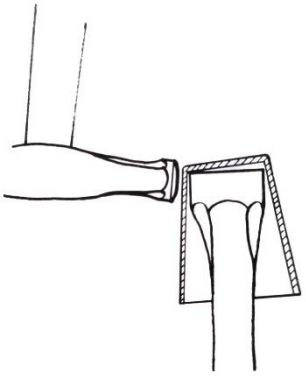


Figure 105: Detachment of the cup wall

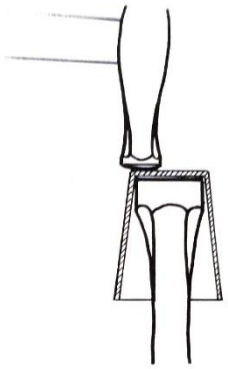


Figure 106: Adjustment of the floor area

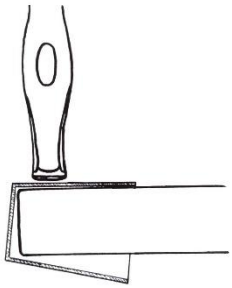


Figure 107: Flattening the cup walls

Figures 6.11 to 6.17 from Brepohl, 1995, pp. 276 – 279.

The lid is made of a thin sheet of copper (<0,5 mm) with a layer of lead (ca 2 mm) (Fig. 106).

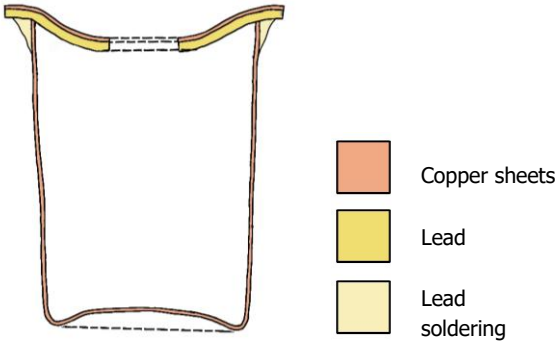


Figure 109: Parts of the inkwell.

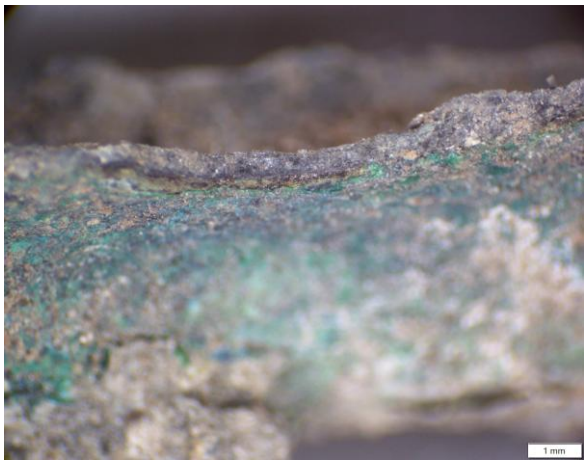


Figure 108: Oblique view of aperture edge of the lid. One grey layer (lead) and one green layer (copper) are visible.

Some inkwells had a movable aperture cover that was attached to the lid (Eckardt, 2017, p. 87). The inkwell is similar to the *Miscellaneous Inkwells with or without Incised Lines on the Body* type describe by Eckardt (2017, p. 93).

Alterations

The inkwell had been buried in the ground since the 4th century AD. It was positioned in the upper soil layers, near the surface.

Jar alterations

The inkwell is sporadically covered with **light brown sediment** spread across its entire corroded and uneven surface. The main corrosion products found are green copper corrosion products in the form of curly malachite, green corrosion products and a small amount of azurite. On the fracture surfaces, it can be seen that the metal is heavily mineralised and dark grey in colour to the centre. Insect exuviae or bodies are present mainly in the upper part of the inkwell, above the large deposits of mineralised organic material, and a big one was inside the jar. A large horizontal, through-going **crack** (face 1), situated in the centre and approximately 3.2 cm wide, is flanked by several smaller ones. **Parts of the metal are missing** around this large crack, revealing the inside of the inkwell, and around the neck. The

jar is **distorted,** especially around the cracks. **Large, slightly curved parallel marks** are visible on the surface (face 3). These were probably made during the excavation and seem like brush marks, which may well have damaged any organic remains. A heavily corroded area on the base of the jar was detected under X-rays (FOOTNOTE See App).

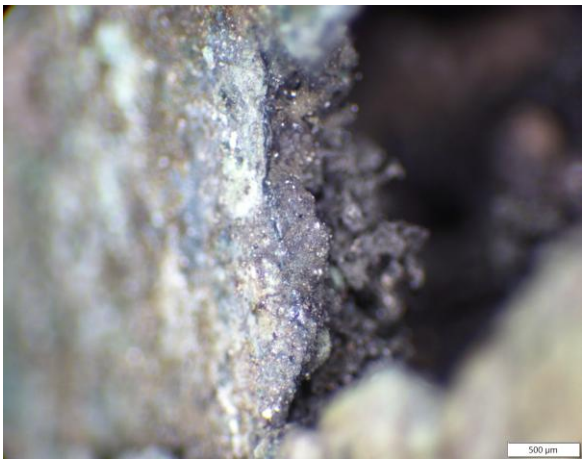


Figure 110: Fracture plane. The metal is really corroded.



Figure 111: Big crack with missing matter.

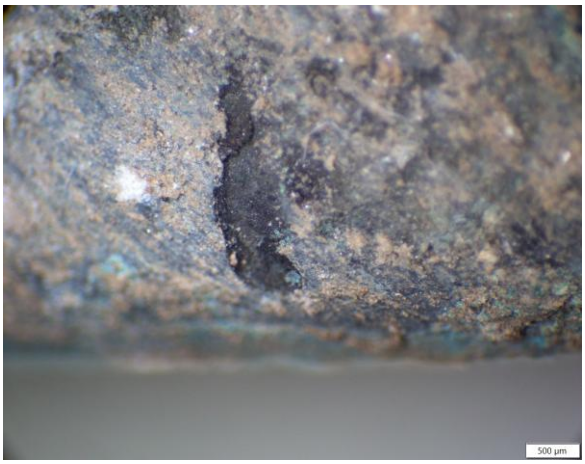


Figure 112: Surface abraded.



Figure 113: Brush traces.

Lid alterations

On the upper surface, there is a smooth **corrosion layer** of copper that split away from the under layers. This corrosion layer grew around some filaments. It may be a fungus[46]. On the

[46] See Documentation appendix, Buckle, Organic documentation, p.121.

outskirt and the inner surface of the lid, the surface is covered with white **lead corrosion products**. Some areas are coloured **black**. The lid is incomplete as the soldering part has a **lacuna**. A fragment of the lid was found in its previous packaging box. The lead sheet has several **lamellar cracks**. The surface is distorted around some of them.

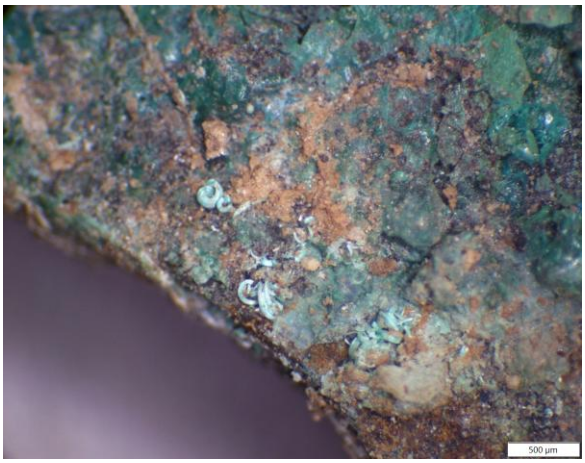


Figure 114: Curly malachite.

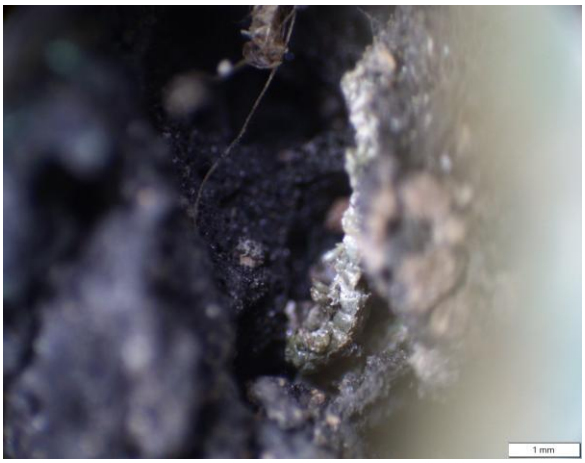


Figure 115: Insect. Exuviae ?

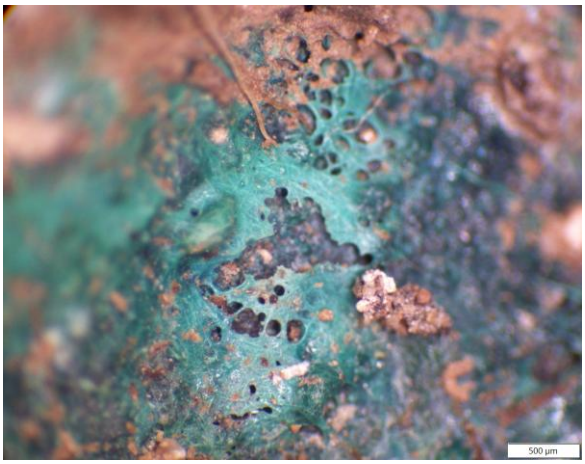


Figure 116: Copper corrosion with filament (fungi?).



Figure 117: Cracks in the lead.

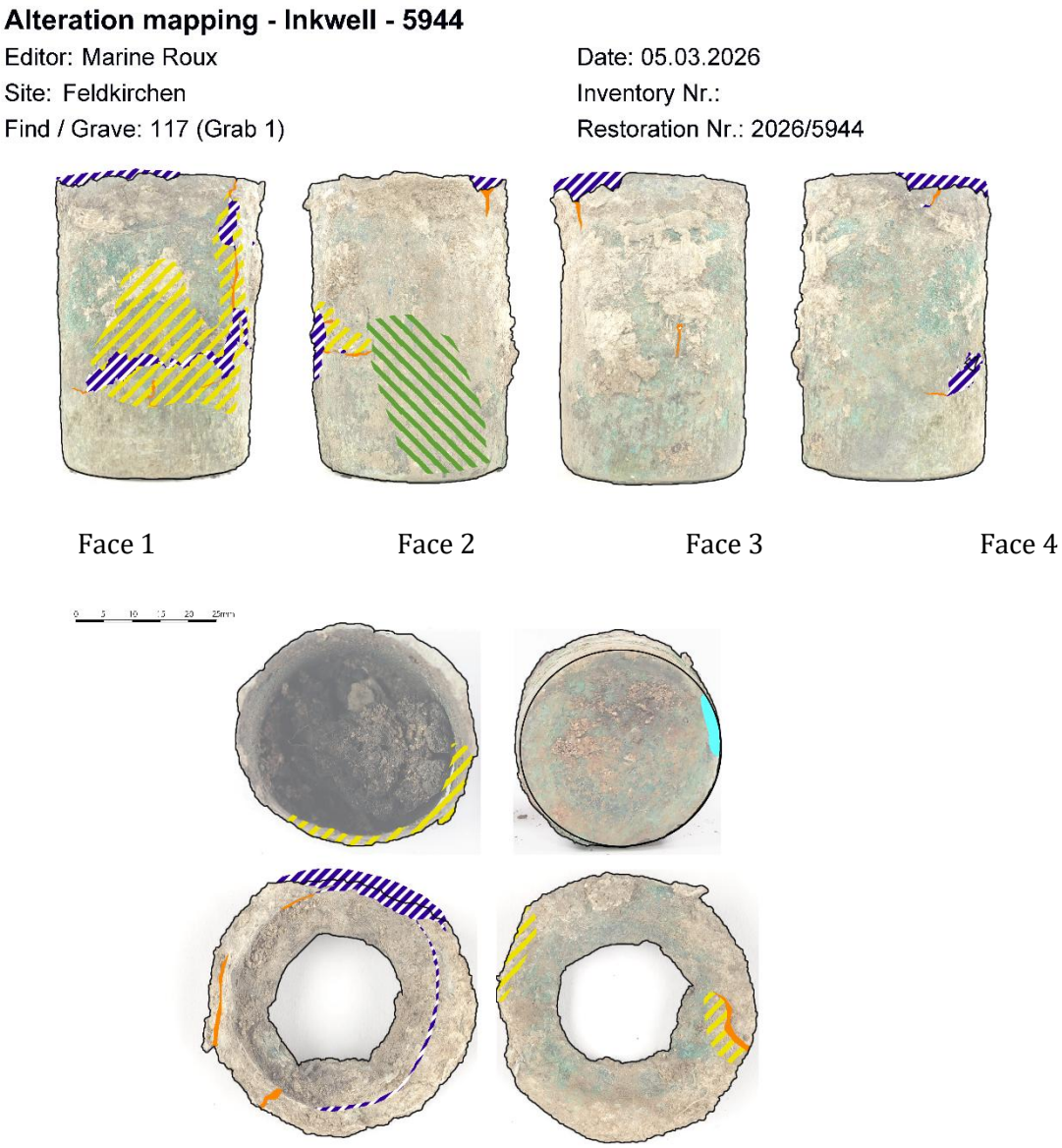


Figure 118: Alteration mapping of the inkwell.

Diagnostic

The time spent buried in a damp environment that is corrosive to metals has caused the inkwell to corrode and led to the build-up of sediment. The combined effect of corrosion and the weight of the sediment has caused deformation and cracking on the surfaces. The corrosion of the lead, which expands more than the metal itself, caused cracks to form on its surface. The brush marks found at the time of discovery may help to pinpoint the surface where the artefact first appeared. Copper corrosion is heterogeneous, revealing a heterogeneous environment. Curly malachite, cuprite or azurite were identified; e.g. azurite formation requires a humid environment with high CO_2 levels coming from decaying organic material.

Pronostic

The big crack with a lacuna and the heavily corroded area of the bottom of the jar are the most fragile parts of the inkwell. If badly handled or packed, inappropriate stress tensions can cause more damage to this fragile part. Copper alloy seems chemically stable as no metal remains, but lead is still very sensitive to organic acids.

Organic documentation

archäologische staatssammlung Fundort **Feldkirchen**: Bearbeiter/in: **Marine Roux**

Rest.Nr **2026/5944** Inv.Nr. **Inv.Nr.**

Organikdokumentation zitieren als:
Roux, Marine 2026: Organikdokumentation 2026/5944, Feldkirchen. Unpublizierter Bericht (Archäologische Staatssammlung München 2026).

Organikdokumentation

Befundbeschreibung / Einzelfunderfassung

REST.NR:	**2026/5944**	INV.NR:	Inv.Nr	
FUNDORT:	Feldkirchen	LANDKREIS:	Bavaria	
LAND:	Germany	SONSTIGE ANM.:	Befund 117, Grab 1	
BEARBEITER/IN:	Marine Roux	START: 09.03.26	ENDE: Enddatum	
OBJEKT(E):	Inkwell	ZEITSTELLUNG:	4th century AD	

*(Bitte nicht vergessen, vor dem Speichern bzw. Drucken den **Dokumentenkopf** und die **Zitiervorlage** auszufüllen.)*

MATERIAL-ANGABEN:	Copper alloy, lead, preserved organic material and ink residues.	GEWICHT:	Lid: 13 g Jar: 21 g
MAßE (*Länge, Breite, Höhe, Durchmesser*):	Jar: D ca 3,7 cm (L 3,8 cm; B 3,6 cm); H 5,2 cm Lid: D ca 4,8 cm (L 3,8 cm; B 5 cm); H 1,3 cm (central hole: D ca 2,2 cm) Vol max: ca 50 cm^3		
LAGE IN FUND-ZUSAMMENHANG:	Above the right shoulder.	AUSRICHTUNG:	North-east, south-west
SCHAUSEITE:	nicht bestimmbar Maybe face 2 (on the mapping) because of brush traces visible from the excavation.		

DOKUMENTATION:	☑ Fotos ☑ Röntgen ☑ Mikroskop ☐ Sonstiges
DOKU-ORDNER:	O:\WERK\BERICHTE\FOTODOKUMENTATION\5901-6000\5944_Feldkirchen#

Kurzbeschreibung und Zusammenfassung der Auswertung:

The inkwell, approximately 6 cm high and 5 cm in diameter, bears mineralised organic remains on its surface, including bast fibre of wood or wood preserved at the top by lead corrosion products and at the bottom by copper corrosion products. The copper corrosion products on the outer surface of the lid have preserved the mould remains, which illustrate the stage of biological degradation of the tomb following burial. Finally, the inkwell contains traces of ancient ink, the composition of which is currently being analysed. The presence of iron in the samples could not be attributed to an ink component. However, it contains soot.
It can therefore be said that the jar was covered with an organic layer, perhaps for decorative purposes, and that the inkwell was placed in the tomb along with its ink. This raises the question of whether there was a stopper made of organic material sealing the lid, which has since disappeared.

*Zum Erweitern von Tabellen: Bitte komplette Zeile von links außerhalb der Tabelle **markieren, kopieren** und mit **Rechtsklick „Zeilen einfügen“***

archäologische staatssammlung Fundort **Feldkirchen**: Bearbeiter/in: **Marine Roux** Rest.Nr **2026/5944** Inv.Nr. **Inv.Nr.**

Beschreibung der organischen Befunde

MATERIALART *(Textil / Leder / Pflanzliche Reste (B) / Holz / Federn (Fd) / Fellhaare (Fh) / Knochen (K) / Horn (Hn) / Substanz bzw. nicht bestimmbare Schicht) / Maße / Lage am Objekt / Zustand usw.:*	
SEITE 1 (*Schauseite*)	
S1	It is located on the jar, all around its external surface, in the form of white and green material with organic morphology. This material has one to four preserved layers, depending on the location on the surface. The least well-preserved layers are located at the bottom. It is predominantly white on the upper two-thirds of the pot and green on the rest. And it consists of alternating vertical and horizontal strip layers. Their morphology looks like bast fibres from plants or trees. Because of their location on the jar, they seem to be part of a material that wrapped the inkwell entirely. Sample: P1 and P2; (Mic.-)Images: 5944_Feldkirchen_M10 / 5944_Feldkirchen_M04
S3	Located mostly on the lid (where this is more visible), some white filaments cover the upper face. They are between 10 µm and 20 µm thick. The copper corrosion has developed across the network and has oval-shaped holes. Sample:--; (Mic.-)Images: 5944_Feldkirchen_M07a
S4	On the lid, a big white deposit is visible on the upper face. Under the microscope, the fragment is a mix of several materials, probably including lead corrosion products (white colour). Some parts look like the same ones from the jar, others that look like textile fibres, and probably some soil. Measures: 7,1 x 4,4 mm. Sample:--; (Mic.-)Images: 5944_Feldkirchen_M07b-f.
S5	A little white deposit is located near the bigger one on the upper face of the lid. This fragment presents morphological aspects of threads that could be part of a textile, but it is difficult to see more information because of the state of preservation. It consists of a white deposit, organic material and soil. Measures: 5,2 x 3,4 mm. Sample:--; (Mic.-)Images: 5944_Feldkirchen_M07g-m.
SEITE 2 (*Rückseite*)	
S2	Located in the jar, a black matter occupies up to 1/3 of the inside. It looks like a mass of botanical matter and is black. The fibres are from 10 µm to 20 µm wide. Almost all the internal surface of the jar is covered with a black powdery substance adhering to the metal corrosion products. This dark powder is distributed all over the inner surface and mostly around the cracks on the surface. The black material on the inner surface could be evidence of an ancient ink. The moving fragments were removed from the inside so as not to lose them during handling, and are kept separately. Sample: P3 and P4; (Mic.-)Images: 5944_Feldkirchen_M01

*(Die Nummerierung erfolgt von **innen nach außen** sowie **Schau- zu Rückseite** bzw. im Boden **oben zu unten** liegender Seite.)*

Seite **2** von **10**

*Zum Erweitern von Tabellen: Bitte komplette Zeile von links außerhalb der Tabelle **markieren**, **kopieren** und mit **Rechtsklick „Zeilen einfügen“***

archäologische staatssammlung | Fundort **Feldkirchen**: Bearbeiter/in: **Marine Roux** | Rest.Nr **2026/5944** Inv.Nr. **Inv.Nr.**

Details zu den naturwissenschaftlichen Analysen

Entnommene Proben

PROBENNR.: **P1**	
Beschreibung: Fragment that fell from the external surface of the jar, consisting of white material with an organic structure with some soil on one face, and copper corrosion products on the other. *Aufbewahrung / Verarbeitung:* SEM stub. *Zugehörige Bilder:* 5944_Feldkirchen_P1_P-Entnahmestelle / 5944_Feldkirchen_P1a / 5944_Feldkirchen_P1b / 5944_Feldkirchen_P1_REM-Traeger. *Fragestellung:* Fibre identification. *Ergebnis:* Under the SEM (REM), some spores (or pollen) were found. They are probably mineralised. No other organic structure was found. The structure of the organic material was too badly preserved.	
PROBENSTANDORT (*nach Analyse*):	P-Standort
VORGENOMMENE ANALYSEN: ☑ REM ☐ EDX ☐ RFA ☐ DLM / PLM ☐ Chemische Untersuchung ☐ Sonstiges	
VERWENDETE CHEMIKALIEN:	Chemikalien

*Für jede Probe kompletten Tabellenblock **kopieren** und hintenan **einfügen**.*

PROBENNR.: **P2**
Beschreibung: Fragment that fell from the external surface of the jar, consisting of white material with organic botanical morphology (aligned fibres in several layers and hollows looking like cells). *Aufbewahrung / Verarbeitung:* SEM stub. *Zugehörige Bilder:* 5944_Feldkirchen_P2_P-Entnahmestelle / 5944_Feldkirchen_P2 / 5944_Feldkirchen_P2a *Fragestellung:* Fibre identification and preservation process. *Ergebnis:* Under a reflected light microscope (Keyence), the white material, from which P1 is sampled, has a parallel and alcove-like structure. The surface is powdery and fragile. The features are not very visible. The organic material is in a poor state of preservation. Under the SEM (REM), the morphological characteristics of wood were found. It is difficult to say if it comes from a piece of **wood or fibres made of it** (tree bast fibres for a weaving or basketry piece of work). The XRF (RFA) revealed a large amount of lead content. With the Mining mode, a detection mode that allows the detection of elements lighter than those detected by the general metal mode used

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for the other measurements, a high amount of arsenic was detected. The mineralisation occurred through lead corrosion.

PROBENSTANDORT (*nach Analyse*):	P-Standort

VORGENOMMENE ANALYSEN:

☑ REM ☐ EDX ☑ RFA ☐ DLM / PLM ☐ Chemische Untersuchung ☐ Sonstiges

VERWENDETE CHEMIKALIEN:	Chemikalien

PROBENNR.: **P3**

Beschreibung: Black powdery material from the inside of the inkwell. The samples were collected scraping the surface. The first attempt (P3.2) was taken with copper corrosion products. A second sample was taken (P3.1) to avoid too much copper contamination.

Aufbewahrung / Verarbeitung: SEM stub.

Zugehörige Bilder: 5944_Feldkirchen_P3_P-Entnahmestelle / 5944_Feldkirchen_P3_REM-Traeger

Fragestellung: Search for traces of ancient ink and identification of iron-based or carbon-based ink.

Ergebnis: Under the microscope, P3 is a black heterogeneous powder, mostly black with light brown and reddish spots.
The SEM coupled with EDX (EDA) allowed to determine light elements (e.g. silica from the soil) and heavier elements like iron-rich particles and lead contaminants. The lead probably came from the lid and soldering material. The iron-rich particles have a peculiar morphology: It is looking like an amalgam of matter with a laminated surface (5944_Feldkirchen_P3_M01_REM).

----> Content of iron can indicate the use of an iron-gall component in the making of the ink. But the results are **not conclusive**, and the results of FTIR analysis made at the Doerner Institut (Munich) tend to contradict the presence of iron-gall ink (See *Weitere Untersuchungen / Bemerkungen*).

PROBENSTANDORT (*nach Analyse*):	P-Standort

VORGENOMMENE ANALYSEN:

☑ REM ☑ EDX ☐ RFA ☐ DLM / PLM ☐ Chemische Untersuchung ☐ Sonstiges

VERWENDETE CHEMIKALIEN:	Chemikalien

PROBENNR.: **P4**

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archäologische staatssammlung Fundort **Feldkirchen:** Bearbeiter/in: **Marine Roux**

Rest.Nr **2026/5944** Inv.Nr. **Inv.Nr.**

Beschreibung: A sample from a black compact powdery material from a movable fragment from the inside of the inkwell. It was selected fragment is powdery and compact, unlike the other botanical-looking bits that were removed from the jar. P4 was scratched from it.

Aufbewahrung / Verarbeitung: SEM stub.

Zugehörige Bilder: 5944_Feldkirchen_P4_P-Entnahmestelle / 5944_Feldkirchen_P4_P-Entnahmestelle_a / 5944_Feldkirchen_P4_REM-Traeger

Fragestellung: Search for traces of ancient ink and identification of iron-based ink or carbon-based ink.

Ergebnis: (Similar to P3)
Once the material was crushed on the stub, the microscopical observation showed a black powder with some lighter elements that likely came from the soil.
The SEM (REM) coupled with EDX (EDA) allowed to determine light elements (e.g. silica from the soil) and heavier elements like iron-rich particles, lead and tin contaminants. The lead probably came from the lid and soldering material. The iron-rich particles have a peculiar morphology. It is looking like an amalgam of matter with a laminated surface or a smooth one.
(5944_Feldkirchen_P4_M01_REM, 5944_Feldkirchen_P4_M02_REM, 5944_Feldkirchen_P4_M03_REM)

----> Content of iron can indicate the use of an iron-gall component in the making of the ink. But the results are **not conclusive**, and the results of FTIR analysis made at the Doerner Institut (Munich) tend to contradict the presence of iron-gall ink (See *Weitere Untersuchungen / Bemerkungen*).

PROBENSTANDORT (*nach Analyse*):	P-Standort
VORGENOMMENE ANALYSEN: ☑ REM ☐ EDX ☐ RFA ☐ DLM / PLM ☐ Chemische Untersuchung ☐ Sonstiges	
VERWENDETE CHEMIKALIEN:	Chemikalien

Weitere Untersuchungen / Bemerkungen

Additionally, XRF (RFA) analysis was done on the big fragment of black material with organic structure (botanical-looking structure) found in the jar (S2, highlighted in dark red on the mapping = VZ_07, M01). The XRF revealed the presence of lead, copper, tin, iron and mercury. Lead, copper, and tin probably come from the object itself (copper alloy and lead soldering). It is difficult to determine whether iron comes from the ink (iron-gall ink?) or the soil. The presence of mercury has not been interpreted yet.

The fragments which P3 (botanical looking one) and P4 (compact one) came from were brought to the Doerner Institute to investigate the presence of an iron-gall ink or of a binder in the black residues with FTIR analysis. The analysis was carried out by Patrick Dietemann and Ursula Baumer.

Seite **6** von **10**

*Zum Erweitern von Tabellen: Bitte komplette Zeile von links außerhalb der Tabelle **markieren**, **kopieren** und mit **Rechtsklick „Zeilen einfügen“***

archäologische staatssammlung Fundort **Feldkirchen**: Bearbeiter/in: **Marine Roux**

Rest.Nr **2026/5944** Inv.Nr. **Inv.Nr.**

They did their own sampling. It did not detect any products that could indicate an iron-gall based ink (iron gall ink, gallic acid or ellagic acid) nor traces of a binder. However, typical polycyclic aromatic hydrocarbons from soot were detected. For better answers, further chemical analysis is needed.
The ink was probably made with soot.

(The fragments were not retrieved yet, and no official report was made besides a presentation of the results by email on the 18.06.2026).

*Zum Erweitern von Tabellen: Bitte komplette Zeile von links außerhalb der Tabelle **markieren**, **kopieren** und mit **Rechtsklick** **„Zeilen einfügen“***

archäologische staatssammlung Fundort **Feldkirchen**: Bearbeiter/in: **Marine Roux**

Rest.Nr **2026/5944** Inv.Nr. **Inv.Nr.**

Auswertung

Several organic residues were identified associated with the inkwell, including white (and green) mineralised organic material located on the external surface of the jar, black material found inside the jar, filaments caught in the copper corrosion of the external surface of the lid and two white fragments of mineralised organic material difficult to identify on the lid too. The white material is made of 1 to 4 preserved layers.

The white material (**S1**) has been identified as wood or tree bast (or just bast fibre?) preserved by lead and copper corrosion products, thanks to microscopical observations and XRF (RFA) analysis. As it was found all around the surface of the jar, it may be interpreted as a matter that covered the metal entirely. A flexible material like bast fibre is more suitable to follow the curve of the jar and would be a better option than wood, without excluding it. Some of the matter was certainly brushed away when it was first found on the site. This face (face 2 on the mapping) can be identified as the visible side of the object during the excavation. Although the corrosion has not been removed, no treatment of corrosion removal has been carried out, and there do not appear to be any decorations on the surface of the pot. No decorations are visible on the X-rays either. Therefore, the hypothesis that an organic casing surrounded the pot is not contradicted by the presence of a decoration that would have been visible. But, even if the layers (at least 4 layers) seem to be placed on the surface perpendicular to the previous one and recall a weaving or basketry type of work, nothing like a weaving pattern is visible. None of the layers seems to go under or on the next one. Either these parts are not visible anymore, or, if this was basketry, the technique used makes it look like that.

The black material (**S2**) inside the jar is most likely the residue of an ancient ink. The dark colour of the inside really stands out from the soil and must be linked to organic remains. The black material is composed of a powdery substance adhering to the internal surface of the jar and clusters of black material that were found loose inside it. Some of these clusters are made of a black compact powder, and others seem to have a botanical morphology (roots or fungi?). The ink's composition was investigated with XRF[1] (RFA), SEM-EDS[2] (REM-EDX) and FTIR analyses[3]. A significant amount of iron compared to the amount found on the rest of the object was detected, which could suggest an iron-gall-based ink. Some grains with high iron content (up to ca 50%) were found in samples from the black powder thanks to SEM-EDS (REM-EDX). However, the FTIR did not show any "iron gall ink, or gallic acid or ellagic acid, respectively", but some goethite and the typical polycyclic aromatic hydrocarbons from soot. Even if the lid was soldered to the jar, they were still found in place but disconnected. The lid also has an opening in the centre. So, without ruling out the possibility of an iron-based compound being present in this ink[4]. Soil contamination could explain the presence of iron. Further analysis will be needed to determine whether the appearance of rich-iron soil is like our images. The soot is a component of a typical recipe for ancient ink; the soot being mixed with a binder. For more information, more in-depth analysis must be carried out (e.g. GC-MS, Gas chromatography–mass spectrometry analysis).

The forms and the thickness of filaments caught in the copper corrosion of the external layer of the lid (**S3**) (c. 10 µm) can be identified as fungi (mycelium?). These are microorganisms involved in the

[1] XRF was carried out on the big fragment with botanical organic material morphology without sampling.
[2] (P3 and P4)
[3] FTIR was done at the Doerner Institute where they did their own sampling. Not known yet.
[4] Oliveira et al. (2025) present a discovery of a mixed ink.

*Zum Erweitern von Tabellen: Bitte komplette Zeile von links außerhalb der Tabelle **markieren**, **kopieren** und mit **Rechtsklick** **„Zeilen einfügen"***

breakdown of organic matter present on the surface or inside the inkwell. An ink based on an organic binder or a decorative bast fibre covering may have been the source of their growth before the toxic effects of copper and lead began to take effect.

S4 and **S5** are difficult to understand because of their small size and aspect. They are probably organic material preserved by lead corrosion product due to their white colour. They seem to present the same morphological aspect of S1 and could come from the same material. There were no samples taken due to the bad state of preservation. If they come from the same material, it would signify that this material went all around the jar and covered a part of the lid (the outskirts at least). Closing mechanisms including a wooden or boned knob on inkwell lids have been described in archaeological context (Eckardt, 2017, p. 78).

---> To conclude, the inkwell was most likely decorated or placed in a covering made of bast fibres (or wood). At last, there was enough organic material for fungi to grow before the copper corroded (or at the same time). And the inkwell was placed in the grave with still ink inside. This raises the question of whether there was a stopper made of organic material sealing the lid, which has since disappeared. One of the ink compounds is soot.

Cited document:

OLIVEIRA, César et al., 2025. Tracing literacy in Roman Conimbriga: insights from the metallurgy and ink of a Biebrich inkwell. *Archaeological and Anthropological Sciences*. Vol. 17, no. 11. DOI 10.1007/s12520-025-02330-3.

ECKARDT, Hella, 2017. Metal inkwells in the Roman Empire. In : Cambridge University Press eBooks, pp. 68–107. DOI 10.1017/9781108284172.005.

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Figure 119: Organic documentation standardised sheet of the inkwell (2026/5944). Some pages are not shown: page 3, the organic mapping presented next, and page 8, the description of the photographic documentation specific to the institution and not relevant here.

Organic mapping

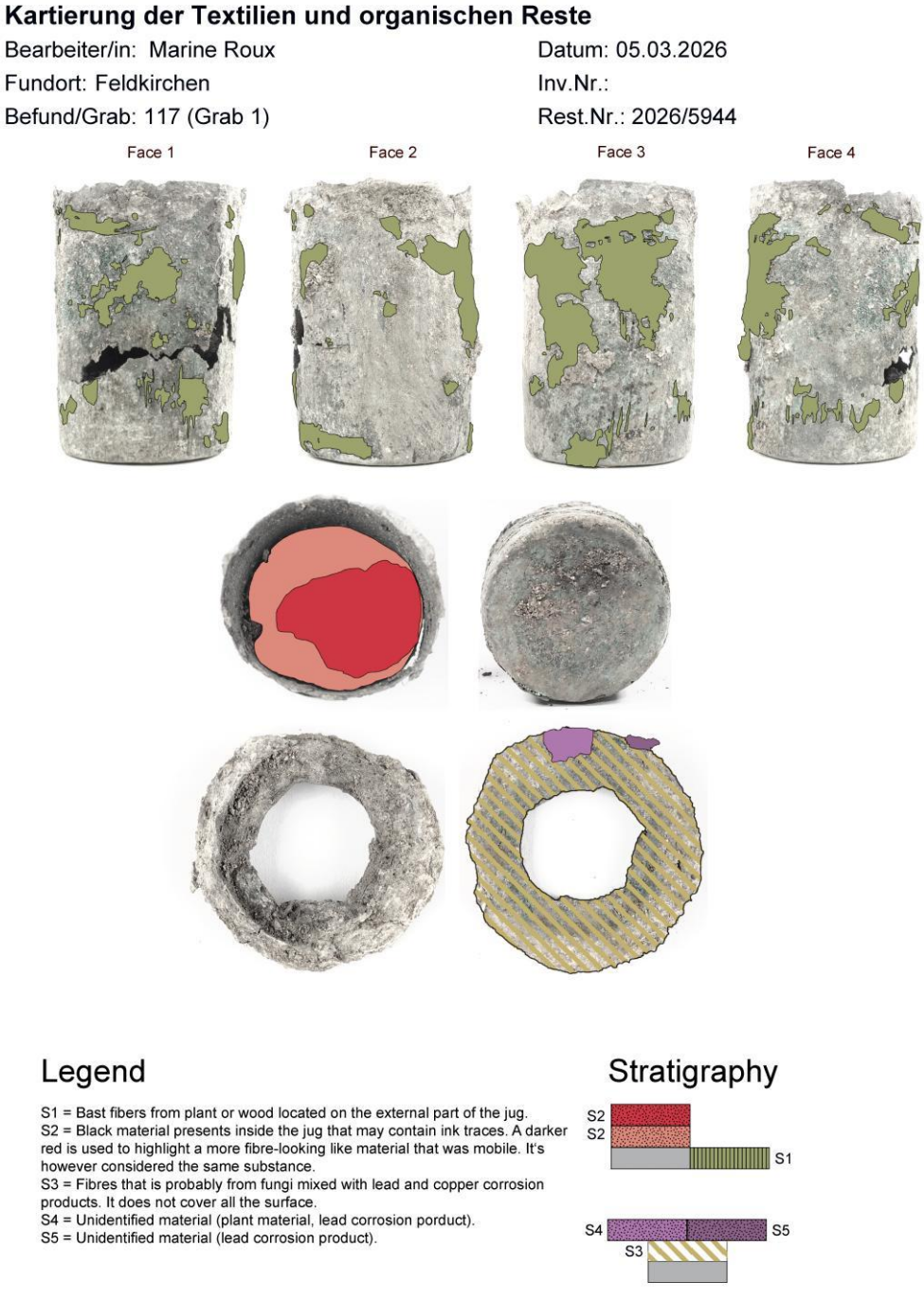


Figure 120: Organic mapping of the inkwell (2026/5944).

Handling recommendations



Figure 121: Handling of the inkwell.

The red zones have to be avoided because of the organic remains. A part is free of organic remains as it was probably brushed away during the excavation. To move the inkwell, lift the jar as shown, placing the thumb on the green spot. It has to be kept in the air for as short a time as possible and placed on a stable surface, such as a tray, to move it.


Lead corrosion is toxic. Always wear gloves for your protection.

1.1.18. Buckle 2026/5945

Condition report

Tableau 4: Identification table of the buckle.

Name	**Buckle**
Inventory n°	//
Restoration n°	2026/5945
Excavation n° (Fz)	116
Feature n° (Bef)	155
Owner	State of Bavaria
Date	4th century AD, Late Roman
Excavation site	St 2082, München-Erding Gde. Ascheim&Feldkirchen Lkr. München
Date of found	1998
Materials	Copper alloy, organic remains
Dimensions	3,5 x 2,8 x 1,5 cm
Weight	8g



Technological study

The buckle was made from a bronze alloy (Cu – Sn). Lead was added to the alloy frame. Lead lowers the melting point when alloyed with other metals (Costa, Urban, 2005, p. 48). The frame was probably cast, and the thorn was hammered around it[47].

Alterations

The buckle is covered in copper corrosion products and sediment from the burial environment. This sediment has dried out and cracked. The thorn is slightly raised. The entire surface of the buckle is corroded. The corrosion is more extensive on the thorn and around the organic remains. The extent of the corrosion and the cracks (Fig. 119, p. 132) on the thorn indicate significant mineralisation, as confirmed by X-ray analysis[48], making it more fragile than the

[47] See Analysis and observations appendix, XRF results, p. 172.
[48] See Photographic appendix, Buckle, p. 100.

rest. Thanks to the X-ray, we can also observe greater mineralisation of the metal around the base of the barb, underneath the mineralised textile remains.

The organic remains are in a poor state of preservation. There is virtually no visible organic material left. Some fibres appear to still contain dark brown organic material (Fig. 120).

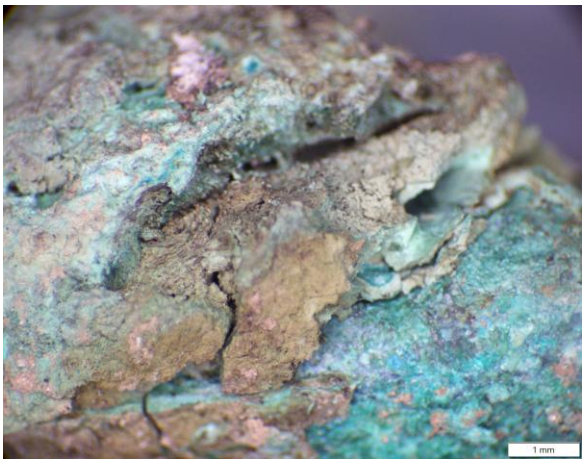


Figure 122: Textile of mineralised textile.



Figure 123: Cracked corrosion on the thorn.

The textile is mostly preserved in the form of a negative mineralisation cast within a porous corrosion deposit, which has poorly preserved the external morphological characteristics of the fibres.

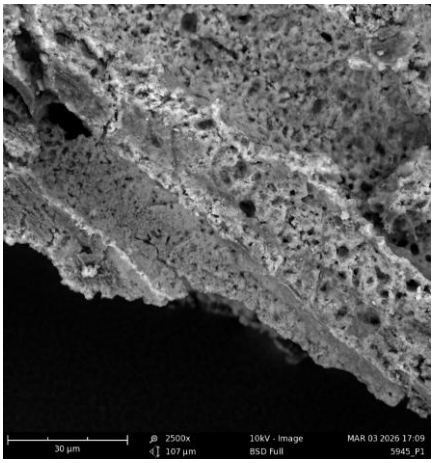


Figure 124: SEM image of negative mineralisation of a fibre in a porous layer of corrosion.

The leather is preserved by positive mineralisation. The pseudomorphs of organic remains (and corrosion) are very fragile, brittle and powdery.

Diagnostic

Cracks can be linked to the drying out of sediments applying stress forces on the corrosion and potentially provoking cracks within it. The alloy thorn was more sensitive to the burial environment. That is why the thorn is more mineralised[49]. The thorn is slightly lifted from the frame because of its position in the belt strap before burial that disappeared. The thorn kept the fixed position when corroding.

There is more corrosion around the mineralised textile: did it create a more aggressive environment for the metal, which allowed rapid corrosion of the alloy and the preservation of the organic remains?

The fibres was preserved by negative mineralisation: the fibres have degraded more rapidly than the corrosion deposit. It is often the case with copper, as it is less mobile than iron, for example, and corrodes more slowly.

Pronostic

The thorn is the most fragile part of the buckle. The buckle is still sensitive to an inappropriate environment. If there is metal in it, the corrosion could grow again. The greater risk is an inappropriate climate. The mineralised organic remains are also sensitive to abrasion.

[49] See Photographic appendix, Buckle, p. 100.

Organic documentation

archäologische staatssammlung Fundort **Feldkirchen** Bearbeiter/in: **Marine Roux**

Rest.Nr **2026/5945** Inv.Nr. **Inv.Nr.**

Organikdokumentation zitieren als:
Roux, Marine 2026: Organikdokumentation 2026/5945, Feldkirchen. Unpublizierter Bericht (Archäologische Staatssammlung München 2026).

Organikdokumentation

Befundbeschreibung / Einzelfunderfassung

REST.NR:	**2026/5945**	INV.NR:	Inv.Nr	
FUNDORT:	Feldkirchen	LANDKREIS:	Bavaria	
LAND:	Germany	SONSTIGE ANM.:	Befund 155, Grab 5	
BEARBEITER/IN:	Marine Roux	START: 18.02.26	ENDE: 30.04.26	
OBJEKT(E):	Buckle	ZEITSTELLUNG:	4th century AD	

*(Bitte nicht vergessen, vor dem Speichern bzw. Drucken den **Dokumentenkopf** und die **Zitiervorlage** auszufüllen.)*

MATERIAL-ANGABEN:	Copper alloy, preserved organic material: textile, leather, botanical remains.	GEWICHT:	8 g
MAßE (*Länge, Breite, Höhe, Durchmesser*):	L 3,5 cm B 2,8 cm, H 1,5 cm		
LAGE IN FUND-ZUSAMMENHANG:	Found near the inner left thigh. Thorn was facing up.	AUSRICHTUNG:	The thorn was showing north.
SCHAUSEITE:	nach oben		

DOKUMENTATION:	☑ Fotos ☐ Röntgen ☑ Mikroskop ☐ Sonstiges
DOKU-ORDNER:	O:\WERK\BERICHTE\FOTODOKUMENTATION\5901-6000\5945_Feldkirchen#

Kurzbeschreibung und Zusammenfassung der Auswertung:

The buckle was found near the abdomen of the deceased. There is mineralised textile on the back and mineralised leather residue on the frame.

As a result, we can say that a leather belt with a copper buckle was placed in the grave with the deceased, either worn by them or laid upon their body. The deceased was wearing a garment made of animal fibres.

Seite **1** von **11**

*Zum Erweitern von Tabellen: Bitte komplette Zeile von links außerhalb der Tabelle **markieren**, **kopieren** und mit **Rechtsklick** **„Zeilen einfügen“***

archäologische staatssammlung Fundort **Feldkirchen** Bearbeiter/in: **Marine Roux** Rest.Nr **2026/5945** Inv.Nr. **Inv.Nr.**

Beschreibung der organischen Befunde

MATERIALART *(Textil / Leder / Pflanzliche Reste (B) / Holz / Federn (Fd) / Fellhaare (Fh) / Knochen (K) / Horn (Hn) / Substanz bzw. nicht bestimmbare Schicht) / Maße / Lage am Objekt / Zustand usw.:*	
SEITE 1 (*Schauseite*)	
S1	Dark brown, almost black, entanglement of what seems to be botanical fibres. It is in the left free space (front view) between the loop and the thorn. It occupies the entire height of the object. The fibres are approximately 0,1 cm thick or less. They are hollow, like tubes. There is no organisation in the fibres that would suggest a textile, but the amount of it (other fragments have been collected with the buckle) and its presence may be related to human intervention. It has been consolidated at a few spots on the back with PB72 in acetone. A loose part located on the front has been removed to have access to the buckle below. All has been documented with microscope images. Sample:--; (Mic.-)Images: 5945_Feldkirchen_M01a-e / 5945_Feldkirchen_M02a-f
L1	Layer of corrosion that contains mineralised leather. We can see the fibres of collagen from the corium. It is located mostly on the front of the buckle in the inner part of the loop. There may be an edge on the base thorn. Sample:--; (Mic.-)Images: 5945_Feldkirchen_ZZ_01
L2	A layer of corrosion that may contain mineralised leather. The morphology is not as clear as the other layer, but the proximity and some hints, like fibres looking like collagen, make it a good guess. Part of this layer near the thorn on the back interior of the buckle is remarkable for its trumpet-like form and smoothness. Sample:--; (Mic.-)Images: 5945_Feldkirchen_ZZ_02
SEITE 2 (*Rückseite*)	
T1	The state of preservation of the mineralised fibres is restraining the amount of information we can get. The textile is preserved in a thick layer of corrosion. T1 lies under T2. T1 (closest to the metal) seems to have thicker threads than T2. It may be constituted of two layers, but it is difficult to say. The thread width is ca. 0,9 cm. This was measured in a very restricted area consisting of 3 visible threads. Sample: P1; (Mic.-)Images: 5945_Feldkirchen_M03 / 5945_Feldkirchen_M05a
T2	The second distinctive layer of textile T2 is made of threads measuring ca. 0,4 cm in width (6 measurements). The weaving is more visible than T1's. T2 lies stratigraphically further away from the metal than T1 (i.e., it is the lower layer of textile in the case the buckle was lying on the deceased, worn as a belt). The distinction between T1 and T2 is yet difficult. Sample: P2; (Mic.-)Images: 5945_Feldkirchen_M03 / 5945_Feldkirchen_M04

*(Die Nummerierung erfolgt von **innen nach außen** sowie **Schau- zu Rückseite** bzw. im Boden **oben zu unten** liegender Seite.)*

*Zum Erweitern von Tabellen: Bitte komplette Zeile von links außerhalb der Tabelle **markieren**, **kopieren** und mit **Rechtsklick** **„Zeilen einfügen"***

archäologische staatssammlung Fundort **Feldkirchen** Bearbeiter/in: **Marine Roux** Rest.Nr **2026/5945** Inv.Nr. **Inv.Nr.**

Textildokumentation

Textilnummer: T1

Lage am Objekt:

The textile remains are located on the back of the object. The back of the buckle is facing down towards the ground, as the buckle was placed on the abdomen with the thorn facing up, and the deceased was lying on their back. It may be composed of two layers because of its thickness.
T1 is the closest to the metal. The thickness could also be explained by the presence of leather under it, but no visual proof was found.

Textilbeschreibung:

The thread organisation is poorly comprehensible because the textile was preserved by negative mineralisation, and this layer is covered by another one (T2). The only places thread of T2 is visible are on the edges of the corrosion bump containing the textile. The threads measured ca. 0,9 cm in places where they could be measured (3 measurements).

Farbe und Material:

The colour was not examined (26.02.2026). Material: animal fibres (presence of scales on the cuticle). It could be a goat, sheep, horse, or any animal that presents a similar hair structure.

Größe:

Ca. 1,2 x 0,65 cm

Beziehung zu anderen Textilresten:

No other relationship is known.

Identifizierung Kette und Schuss:

No.

Gewebetechnische Details:

	Fadensystem 1 (-Verlauf)	**Fadensystem 2** (-Verlauf)
Garn/Zwirn	Z	Z (?)
Fadendrehung	--	--
Drehwinkel	--	--
Fadenstärke	ca. 0,9 mm	No measurement possible
Gewebedichte (Fäden pro cm)	--	--

FS1/2: Stärke (FS1/2; cm) * Dichte (FS1/2) = xx

→ *Abdeckfaktor*: FS1 + FS2 – (FS1 * FS2) = yy
→ Auswertung nach Hammarlund 2004

[*Doppelfäden: Gewebedichtewert muss der*

Abdeckfaktor:

Seite **4** von **11**

Zum Erweitern von Tabellen: Bitte komplette Zeile von links außerhalb der Tabelle ***markieren, kopieren*** *und mit* ***Rechtsklick „Zeilen einfügen“***

archäologische staatssammlung Fundort **Feldkirchen** Bearbeiter/in: **Marine Roux** Rest.Nr **2026/5945** Inv.Nr. **Inv.Nr.**

Textilnummer: T2

Lage am Objekt:

This layer of mineralised textile is located on T1. As the buckle was probably lying on the deceased, worn as a belt, it is the lower of the two textile layers.

Textilbeschreibung:

The threads are only visible where the corrosion was abraded on the surface. They have a width of ca. 0,4 cm (6 measurements) and are practically not twined. At this stage, because of the poor state of preservation of the textile fibre, it is rather difficult to identify the textile weave, to evaluate the threads' twirl, or the density of each thread system with certainty. It seems that thread system 1 is not dense, quite open (see *Gewebetechnische Details*) because the threads seem to be spaced apart by a distance roughly equal to the width of a thread. The thread system 2 is more difficult to discern. Even if it seems denser, we cannot say for sure. The disorganised appearance of the textile fibres may be due to the presence of 2 layers of it without accurate proof.

Farbe und Material:

The colour was not examined (26.02.2026). Material: animal fibres (presence of scales on the cuticle). It could be a goat, sheep, horse, or any animal that presents a similar hair structure.

Größe:

Smaller than 1,2 x 0,65 cm.

Beziehung zu anderen Textilresten:

No other relationship is known.

Identifizierung Kette und Schuss:

No.

Gewebetechnische Details:

	Fadensystem 1 (-Verlauf)	**Fadensystem 2** (-Verlauf)
Garn/Zwirn	Z (?)	Z (S)
Fadendrehung	--	--
Drehwinkel	--	--
Fadenstärke	ca. 0,4 mm	No measurement possible
Gewebedichte (Fäden pro cm)	ca. 8 – 9 T / cm* (counted on 5mm)	/

*As a hypothesis, it remains difficult to properly identify enough threads of the system 1.

FS1/2: Stärke (FS1/2; cm) * Dichte (FS1/2) = xx

→ *Abdeckfaktor*: FS1 + FS2 – (FS1 * FS2) = yy
→ Auswertung nach Hammarlund 2004

[*Doppelfäden: Gewebedichtewert muss der*

Zum Erweitern von Tabellen: Bitte komplette Zeile von links außerhalb der Tabelle ***markieren, kopieren*** *und mit* ***Rechtsklick „Zeilen einfügen"***

archäologische staatssammlung Fundort **Feldkirchen** Bearbeiter/in: **Marine Roux**

Rest.Nr **2026/5945** Inv.Nr. **Inv.Nr.**

Details zu den naturwissenschaftlichen Analysen

Entnommene Proben

PROBENNR.: **P1**	
Beschreibung: FS1 and FS2 from the T1 layer (closest to the metal). Mineralised textile fragments from the back of the buckle. *Aufbewahrung / Verarbeitung:* SEM-stub. *Zugehörige Bilder:* 5945_Feldkirchen_ P1_REM-Traeger / 5945_Feldkirchen_P1_P-Entnahmestelle / 5945_Feldkirchen_M03 *Fragestellung:* Fibre identification and see if it discriminates between T1 and T2. *Ergebnis:* In cross-section under a reflected light microscope (Keyence), the fibres are mostly round but sometimes oval. Their width varies on average between 25 and 35 µm and ranges from 20 to 50 µm (M05c_T1_FS2). FS1: The sample for FS1 was collected in an area where the corrosion is porous (REM_16 a_FS1). The corrosion fragments show fibre impressions, in some of which cuticle or scale imprints are visible, even though they are not very clear (REM_02, 06). The fibre imprints measured have a width of ca. 20-40 µm. One fragment stands out, as it appears to be part of a mineralised medulla from an animal fibre (REM_21 a_FS1). It has a wide lattice structure (Rast-Eicher 2016, p. 13). It is 64 µm wide, making it bigger than all the measured ones from P1 and P2, too. The fibres measured are from 20 to 40 µm wide (apart from the latter). FS2: Under the SEM (REM), it is possible to observe the imprint of a cuticle with scales that identify the fibre as being of animal origin. The scales form is a mosaic one, more a regular one with some aspects of flat and irregular mosaic (Rast-Eicher, 2016, p. 13) (5945_Feldkirchen_P1_REM_17 a_FS2). The fibres measured are from 24 to 44 µm wide. From what is still visible on the imprint of the fibres, the scales present an intermediate position in relation to the longitudinal direction of the hair (between transversal and longitudinal). The pattern can be described as a mix of broad petals and mosaic. The scales' margins are smooth and rippled, and the space between each is rather distant (Teerinck 1991, p.7). Hypothesis remains uncertain, but the animals that most match the observations are the sheep, the goat, and, to a lesser extent, the horse. As the width is similar for FS1 and FS2, we can assume that the used fibre is the same for both. → FS1 and FS2: animal hair.	
PROBENSTANDORT (*nach Analyse*):	P-Standort
VORGENOMMENE ANALYSEN: ☑ REM ☐ EDX ☐ RFA ☐ DLM / PLM ☐ Chemische Untersuchung ☐ Sonstiges	

*Zum Erweitern von Tabellen: Bitte komplette Zeile von links außerhalb der Tabelle **markieren**, **kopieren** und mit **Rechtsklick „Zeilen einfügen“***

archäologische staatssammlung Fundort **Feldkirchen** Bearbeiter/in: **Marine Roux** Rest.Nr **2026/5945** Inv.Nr. **Inv.Nr.**

VERWENDETE CHEMIKALIEN:	Chemikalien

*Für jede Probe kompletten Tabellenblock **kopieren** und hintenan **einfügen**.*

PROBENNR.: **P2**

Beschreibung: FS1 (S1) and FS2 (S2) from the T2 layer (furthest to the metal). Mineralised textile fragments from the back of the buckle.

Aufbewahrung / Verarbeitung: SEM-stub.

Zugehörige Bilder: 5945_Feldkirchen_P2 _REM-Traeger / 5945_Feldkirchen_P2_P-Entnahmestelle / 5945_Feldkirchen_M05

Fragestellung: Identification of the fibre and see if it discriminates T1 and T2.

Ergebnis: P2 samples yielded better visual results than P1 samples due to less porous corrosion, which better preserved the cuticle's scales (5945_Feldkirchen_P2_REM_01 a_FS1). Under the SEM (REM), it is possible to observe the imprint of a cuticle with scales that identify the fibre as being of animal origin. The scales have a mosaic pattern, mostly regular with some aspects of flat and irregular mosaic (Rast-Eicher, 2016, p. 13) (5945_Feldkirchen_P2_REM_03 a_FS1). From what is still visible on the imprint of the fibres, the scales present an intermediate position in relation to the longitudinal direction of the hair (between transversal and longitudinal). The pattern can be described as a mix of broad petals and mosaic. The scales' margins are smooth and rippled, and the space between each is rather distant (Teerinck, 1991, p.7). Hypothesis remains uncertain, but the animals that match the observations the most are the sheep, the goat, and, to a lesser extent, the horse for both thread systems.
FS1: The fibre width measures between 20 and 50 µm. No cross-sections were observed for FS1.
FS2: The fibre width measures between 25 and 30 µm. In cross-section under a reflected light microscope (Keyence), the fibres are mostly round but sometimes oval. Their width varies on average between 25 and 35 µm and ranges from 20 to 50 µm. (M05c_T1_FS2).

→ FS1 and FS2: animal hair.

PROBENSTANDORT (*nach Analyse*):	P-Standort

VORGENOMMENE ANALYSEN:

☑ REM ☐ EDX ☐ RFA ☐ DLM / PLM ☐ Chemische Untersuchung ☐ Sonstiges

VERWENDETE CHEMIKALIEN:	Chemikalien

*Für jede Probe kompletten Tabellenblock **kopieren** und hintenan **einfügen**.*

Weitere Untersuchungen / Bemerkungen

Sonstige Untersuchungen / Bemerkungen

*Zum Erweitern von Tabellen: Bitte komplette Zeile von links außerhalb der Tabelle **markieren**, **kopieren** und mit **Rechtsklick** **„Zeilen einfügen"***

archäologische _staatssammlung Fundort **Feldkirchen** Bearbeiter/in: **Marine Roux** Rest.Nr **2026/5945** Inv.Nr. **Inv.Nr.**

Auswertung

Several organic residues could be identified on the buckle, including botanical material, two mineralised textile layers, and mineralised leather. The botanical material is situated in the space between the thorn and a side of the frame. The leather is quite difficult to see, but we can see potential residue near the base of the thorn and on the frame. The textile is located on the back of the buckle. For the mapping, refer yourself to the organic mapping on p. 3. The state of preservation of the mineralised organic remains is bad and makes their observation and understanding difficult.

Because of the mineralised textile state of preservation, technical information about the textile is limited to the potential layer number of textiles and the nature of the fibre used. The thread thickness was measured in some of the visible threads for both textile layers but should be treated with caution as a representation of the whole, as it was measured on too few occasions and only on one of the thread systems of each. A proper assessment of the thread system could not be done as twist angle and weave density measurements could not be realised.

Nevertheless, we can say that there are at least 2 layers that are likely from two different textiles, the one closest to the metal presenting wider threads than the one above. And that, judging by the microscopic images, were made both of sheep, goat, or, less likely, horse fibres. If the belt is being worn, the position of the textile beneath the back of the buckle suggests that the fabric is more likely to be a garment rather than a shroud. Also, it is more likely one or two garments rather than a textile belt due to the presence and distribution of the leather residues. Technical variations within the same fabric are usual in handcrafted production. The differences between T1 and T2 may therefore indicate that there are two different fabrics, or it could be a folded fabric.

The state of preservation of the leather does not allow animal identification. The presence of leather around the base of the thorn and on ca 1/3 of the frame may indicate the presence of a leather strap belt. The two organic layers interpreted as leather seem to belong together. However, it is difficult to determine the exact arrangement of the belt. There are known cases of belts coiled around themselves and placed at the abdomen (and therefore not worn)[1]. But since no leather residue was found on the thorn or in several layers, it is more convenient to imagine that the belt was worn. The small amount of leather that remains does not allow us to state this with certainty.

The botanical remains were not further studied. Loose fragments and in-place ones are kept. Without additional information, we cannot be sure whether this is material which was intentionally added to the burial or has grown into it at some point. Indeed, botanical garnishment such as a carpet of grass or a bouquet of plants is not unusual.

We can say that a leather belt with a copper buckle was placed in the grave with the deceased, either worn by them or laid upon their body. The deceased was wearing a garment made of animal fibres.

Cited document:

Bizot, B., & Signoli, M. (2009). *Rencontre autour des sépultures habillées*.

[1] Bizot, Signoli 2009, p.97

*Zum Erweitern von Tabellen: Bitte komplette Zeile von links außerhalb der Tabelle **markieren**, **kopieren** und mit **Rechtsklick** **„Zeilen einfügen“***

Figure 125: Organic documentation standardised sheet of the inkwell (2026/5944). Some pages are not shown: page 3, the organic mapping presented next, and page 5, 7 and 8, including the description of the documentation specific to the institution and not relevant

Organic mapping

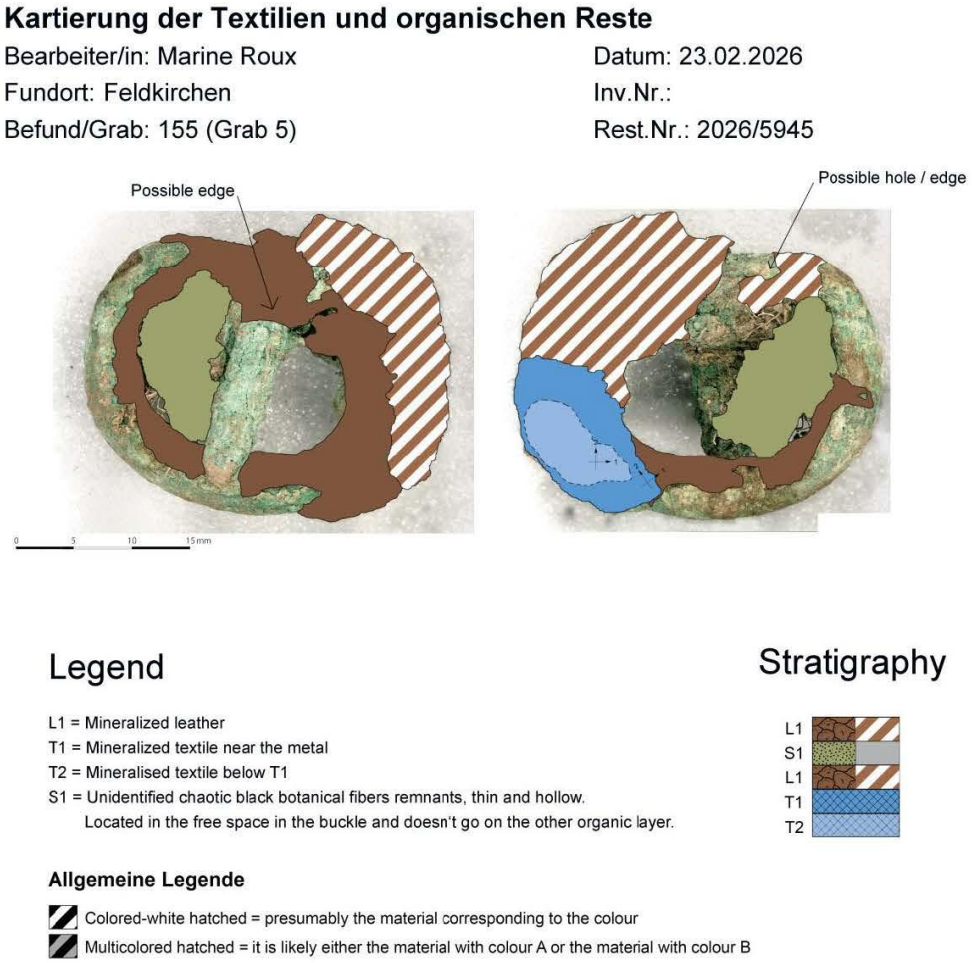


Figure 126: Organic mapping of the buckle (2026/5945).

Handling recommendations



Figure 127: Handling of the buckle.

The red areas are the fragile areas and the location of the organic remains. There are to be avoided.

1.1.19. Consequences of the application of P-B72 on a mineralised textile thread

Context

Applying a protective layer of resin to an archaeological surface is a very common practice in conservation and restoration. Its purpose is to consolidate the surface and protect it from the external environment, either temporarily or for a longer period, such as during exhibition or storage, to ensure its preservation. In archaeology, a surface may sometimes be temporarily consolidated, particularly when a fragile artefact is discovered and lifted as a block, for example. This protective layer is therefore temporary and, in practice, reversible. However, in the case of mineralised organic remains, it has been reported that such treatment is harmful and can impact their identification. Resins obstruct observations under a scanning electron microscope (SEM), and solvents degrade the fibres (Rast-Eicher, 2016). The recommended practice is therefore not to apply any treatment to mineralised organic remains before their analysis. As analytical techniques evolve and can give new results on samples already studied, a long-term protective layer should also be avoided.

However, it may be necessary to apply resin or use a solvent, as mineralised organic remains are never found alone and can themselves need consolidation. The conservation issues relating to metallic objects must also be taken into account. Similarly, objects sometimes arrive at the laboratory already coated in resin, having been protected after excavation.

Protocol

This observation aims to assess the impact of applying a layer of Paraloid B72 resin diluted to 10% in acetone and its removal in an acetone bath, as well as the physical forces involved (applying the resin with a brush, handling with tweezers, the dip in the bath). The choice of resin was based on the laboratory's restoration practices. This observation was possible by using threads made of bast fibres that had been mineralised by iron corrosion products and separated from their original context.

A, B and C, three fragments of thread separated from the textile layers on the bracelets (2026/5943) found in the storage box of the bracelets, are all the same size, appearance and nature.

- A = control fibre
- B = fibre with resin on
- C = fibre after an acetone bath

The three fragments are similar in colour, thickness, appearance and nature, making them comparable in how they will react.

1. Preliminary steps:

1.1. The fibres were examined under a binocular magnifying glass to document their surface condition and appearance.

1.2. A sample of each was taken to confirm that they were of the same type: bast fibres.

2. Preparation phase:

2.1. Application of PB72 resin at 10% in acetone on fibres B and C.

2.2. Remove the resin from the C-fibre using an acetone bath after at least one week to ensure the resin has fully polymerised (record of time sitting in the bath, number of different baths, and acetone quantity). The complete removal of the resin is being assessed under the binocular magnifying glass under the same conditions as during conservation treatment on an object.

3. Observation:

3.1. Preparation and observation of the three samples following preparation of the stub for SEM analysis.

3.2. Description and conclusion.

Results

The first bath removes a large amount of resin, but it is still well visible. By visual assessment, the glue was removed from ca 60% of the fibre. The thread gets back its original colour, and the surface is less glossy. From the third bath, the thread was as fragile as before the coating. Some fibres were dissociated from the thread during the handling. After the fourth bath, it was more difficult to assess the amount of resin left.

The assessment of resin presence was based on whether or not reflections were observed on the surface or whether the colour differed from that of fibre A, as noted by the observers. Finally, the 7th bath served as a safety bath to ensure maximum removal based solely on visual inspection.

SEM observation confirmed the complete removal of resin from the observed surface of the filament. However, the fibres are damaged compared to Sample A. This damage is attributed to the handling of the fibre with tweezers between the bath container and the stereomicroscope stage. Longitudinal cracks in the corrosion layer covering the fibres are more numerous than on the A threads. However, it is difficult here to attribute this observation to the action of the solvent or to any other factor related to the application of a protective coating. A fibre that is still largely organic is visible and does not appear to have been affected by handling (no cracks). It is still possible to identify the nature of the fibre: bast fibre.

Conclusion

Identification is still possible after complete resin removal. However, it should be noted that when identifying the fibre of a textile thread, a smaller sample would be taken. If the fibres are well preserved, they would be separated to facilitate observation, whether under a PLM microscope or an SEM. A layer of adhesive would not necessarily hinder this procedure, as any uncovered fibres would remain accessible.

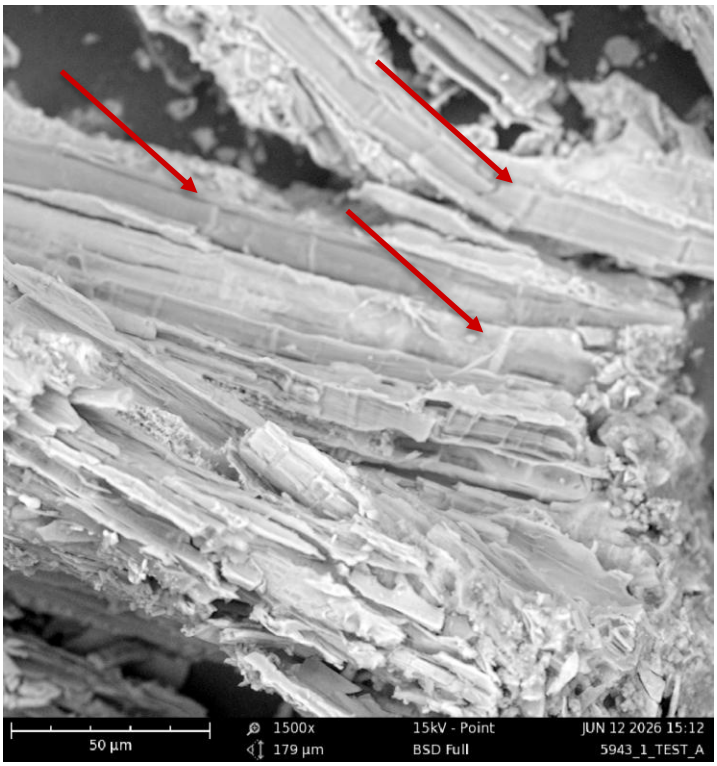
The most significant damage is due to handling and the stresses applied to the thread during handling. The corrosion layer may have been damaged; some fibres are broken, and a fibre that was almost entirely free of mineralisation was discovered beneath the corrosion layer.

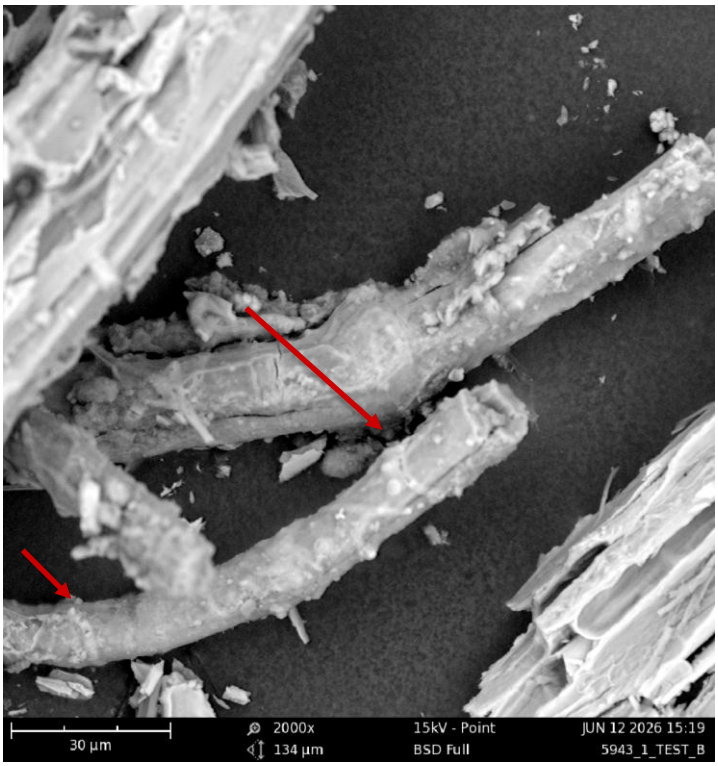
Paraloid is reversible, but this resin had been applied 10 days earlier. The behaviour of the resin may change over time and lose its reversibility. Removal might have required more baths or longer baths. Furthermore, the influence of the quantity and duration of the baths has not been assessed. Also, the fibre was preserved by positive mineralisation and was in a good state of preservation.

Documentation



Figure 128: Microphotographies of the three chosen fibres under stereomicroscope.




30 µm
2000x
134 µm
15kV - Point
BSD Full
JUN 12 2026 15:19
5943_1_TEST_B

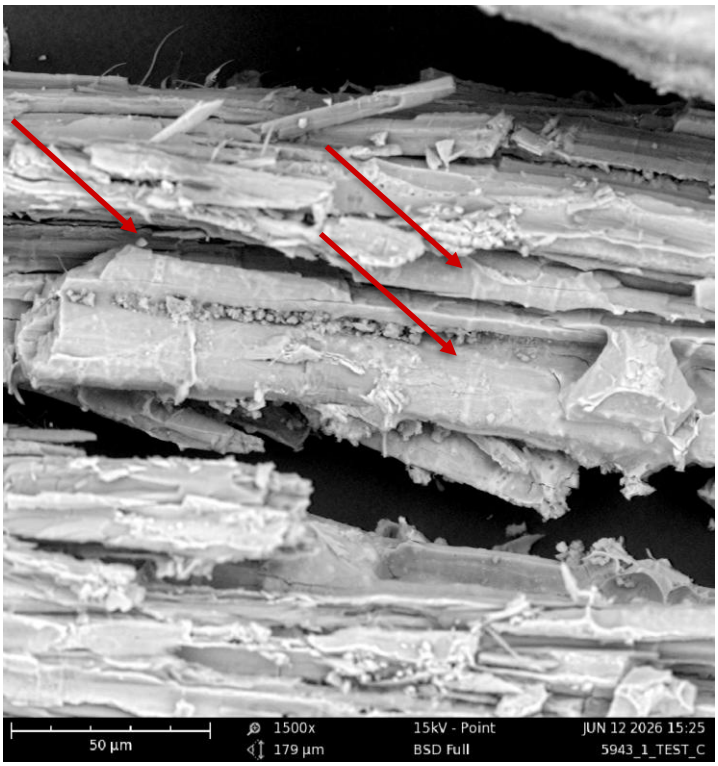


Figure 129: Fibre identification: bast fibres. Nodes showed by red arrows.

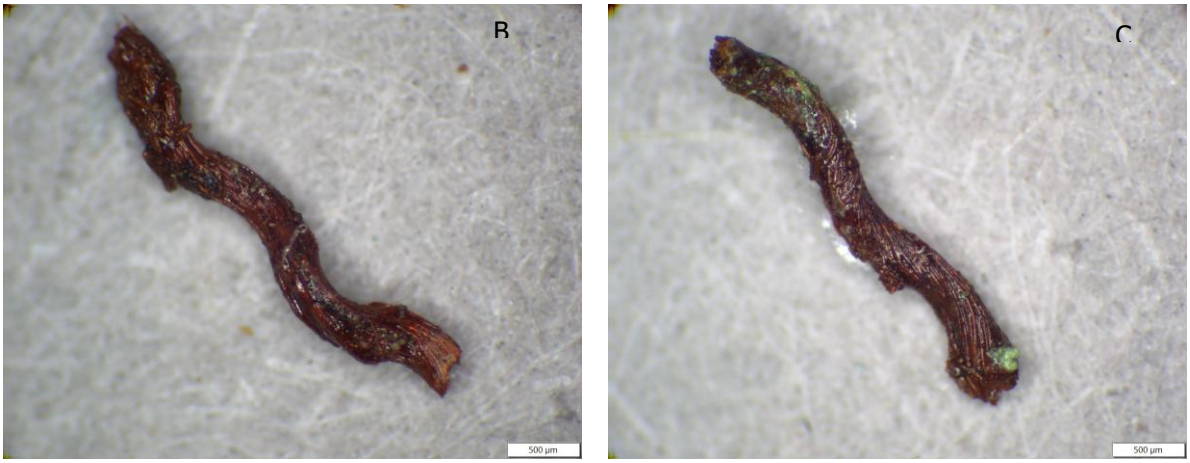


Figure 130: Microphotographies of B and C fibres after coating with PB72 10% in acetone under a binocular microscope.

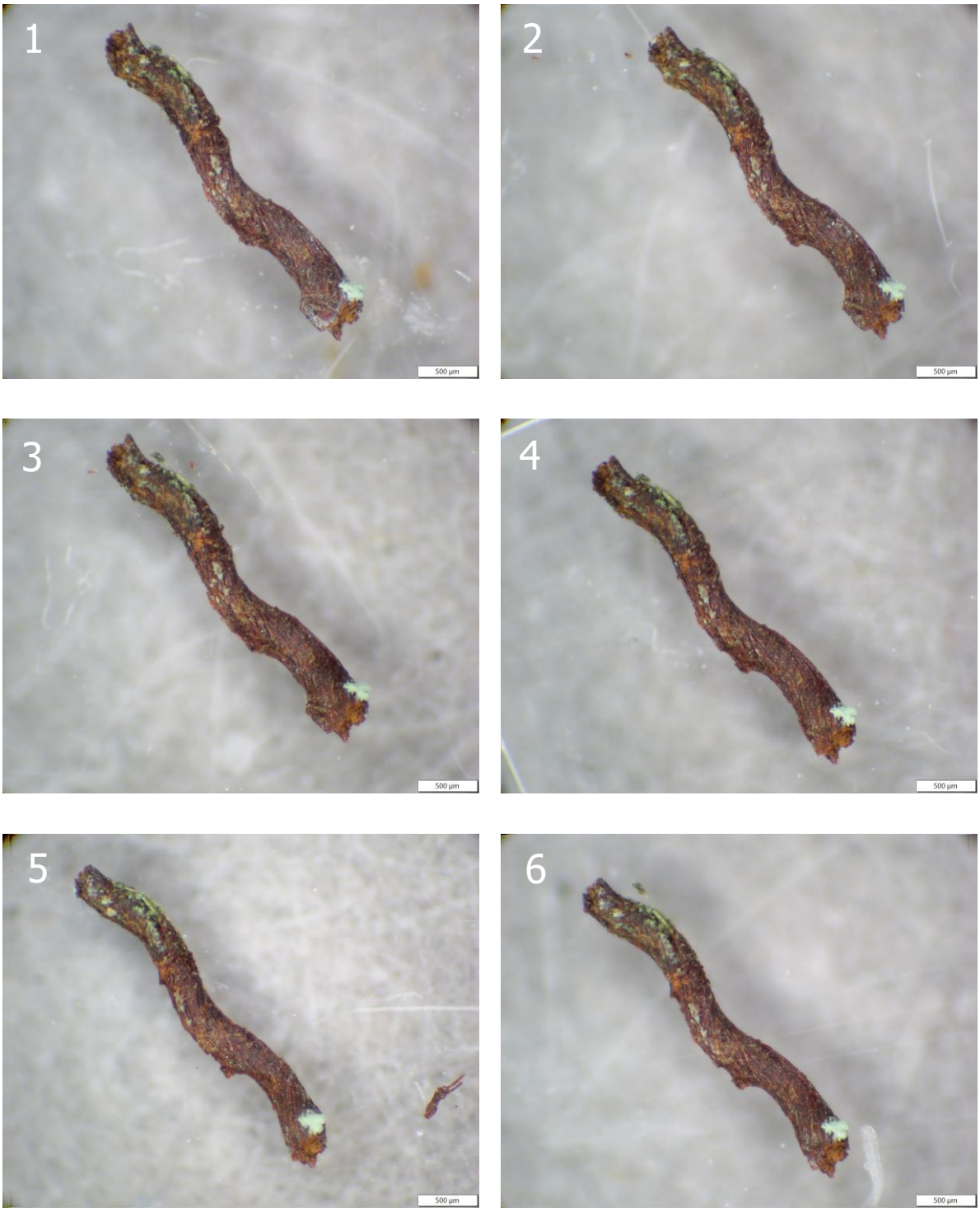

1
500 µm
2
500 µm
3
500 µm
4
500 µm
5
500 µm
6
500 µm



Figure 131: Microphotography between each bath (1ml acetone, 30 seconds).

Analysis and observations appendix

1.1.20. XRF results

Technique: Non-destructive and portable X-ray fluorescence analysis (p-XRF). Using this method, different materials can be qualitatively and semi-quantitatively detected by excitation with X-rays.

Tool: XRF Niton™ XL3t analyser from Thermo Fisher Scientific.

Operator: Peter Albert

Analysis window diameter: 3mm

Bracelets – Rest.Nr: 2026/5943

Aims: To specify the chemical composition of the alloy to gain a better understanding of the metal's deterioration, the mineralisation process of the textile on bracelet 1, and to identify potential surface treatments (light grey metallic surface on bracelets 3).

Acquisition mode: General Metals mode

Acquisition time: 60s

Measurement locations

Bracelet 4

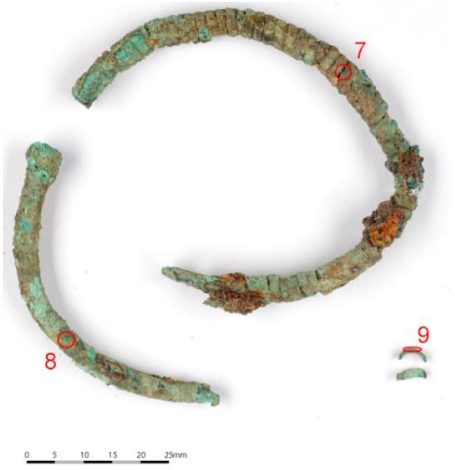


Bracelet 3



Lower face (near the hand) *Upper face (towards the arm)*

Bracelet 2





Lower face (towards the hand) *Upper face (towards the arm)*

Bracelet 1





Upper face (facing the arm) *Lower face (near the hand)*



Photography showing the fragments' placement on the bracelet

Fragment of mineralised organic material, one of which contains a fragment of iron coming from a second ring adhering to the bracelet (second bracelet?).

Analytical data

" - " replaces "<LOD" (limit of detection) in the tabs, and important elements are highlighted.

Results were rounded to the nearest tenth.

2026/ 5943	Nr	**Sb**	**Sn**	**Ag**	**Pb**	**Hg**	**Au**	**As**	**Zn**	**Cu**	**Co**	**Fe**	**Ti**
Bracelet 4	**1**	0,1	1,1	32,8	0,7	-	0,12	0,2	-	63,4	-	1,2	0,2
	2	0,1	1,3	31	0,4	0,03	0,1	-	-	66,9	-	0,2	-
Bracelet 3	**3**	0,1	1	23,1	0,3	-	-	0,1	0,7	74,1	-	0,5	-
	4	0,1	1,4	33,1	0,4	0,06	0,1	-	-	63,7	-	1	-
	5	0,1	0,8	18	0,3	-	0,1	0,1	0,6	68,8	-	11,1	-
Bracelet 2	**6**	0,2	10,4	-	0,6	-	-	0,1	2	86,1	-	0,3	0,2
	7	0,2	8	-	2,3	-	-	0,5	9,1	78,4	-	1,3	0,1
	8	0,1	4,8	-	1,2	-	-	0,1	7,2	84,5	-	1,8	0,1
	9	0,2	4,5	-	1,5	-	-	-	6,9	86	-	0,7	-

Bracelet 1	**10**	0,3	11,9	-	0,1	-	-	1,0	0,3	46,6	-	39,5	-
	11	0,2	3,9	-	1,2	-	-	0,4	0,2	69,5	-	24,0	0,1
	12	0,1	0,1	-	0	-	-	0,1	1	17,4	0,2	81	-
	13	0	0	-	0,4	-	-	0,2	0,5	33,1	0,3	65,2	-

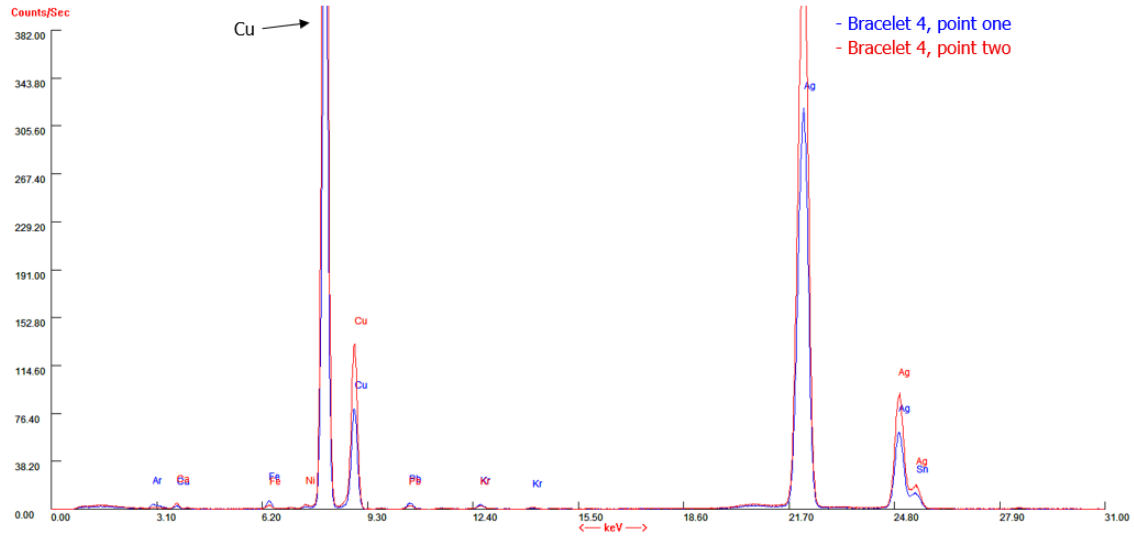
Bracelet 3 and **bracelet 4** are similar not only in shape but also in composition. The amount of silver found (c. 30% Ag) is not high for an alloy, but the partial removal of corrosion and a break on one end of bracelet 3 proved they were made of a silver alloy. Trace amounts of mercury and gold probably derive from the silver ore (Mišta-Jakubowska et al, 2019, p. 3351). Lead could come from the ore itself. Antimony and arsenic are trace elements from the copper (Bougarit and Mille, 2014, p. 107), like iron. However, higher iron concentrations were recorded (1 and 5). The presence of iron is likely the result of contamination from nearby iron elements (on bracelet 1).

Bracelet 2 consists of a wire core around which a second wire is wound. Analysis revealed a copper-based quaternary alloy (Cu, Sn, Zn, Pb). However, the composition of the wire appears to exhibit a higher zinc content compared to the core, with zinc levels ranging from 7% to 9%, compared with approximately 2% in the core.

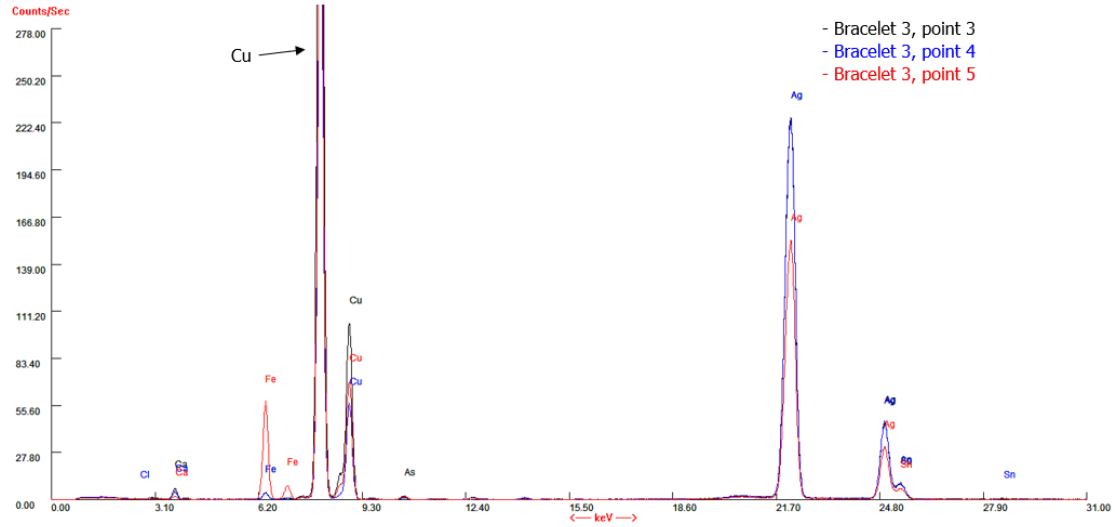
For **bracelet 1**, the first measurement (10) was conducted on the copper part of the bracelet, whereas the last three measurements (11 and 13) were conducted on a fragment adhering or formerly adhering to the bracelet. The presence of substantial cross-contamination between the bracelet and the fragment complicates the interpretation of the results, as it becomes difficult to distinguish between the results of the two. This issue is further complicated by the fact that the twisted bracelet, which currently consists of two wires of copper alloy, probably originally incorporated a third wire of iron, which has disappeared. Nevertheless, it can be said that the fragment (or fifth bracelet) was made of iron and that the copper part of **bracelet 1** was composed mostly of copper and tin.

Spectra

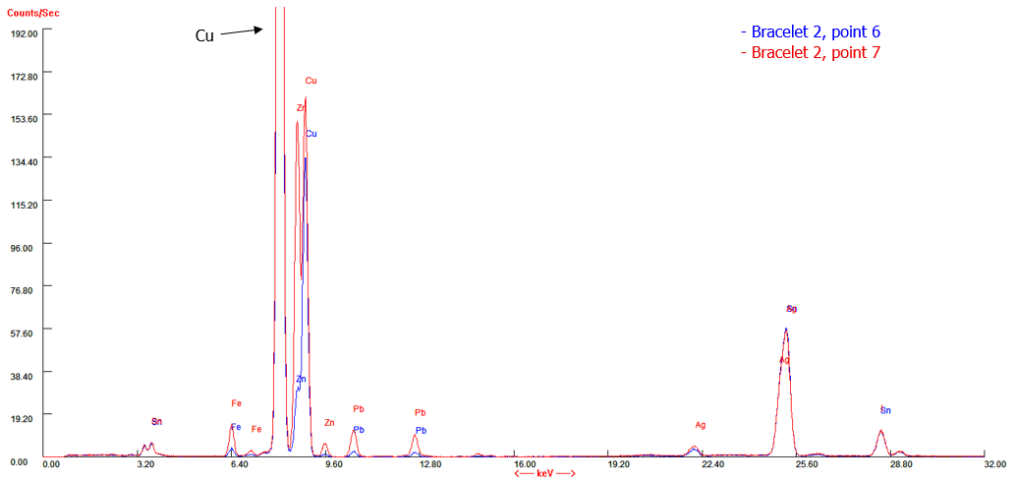
Bracelets 4

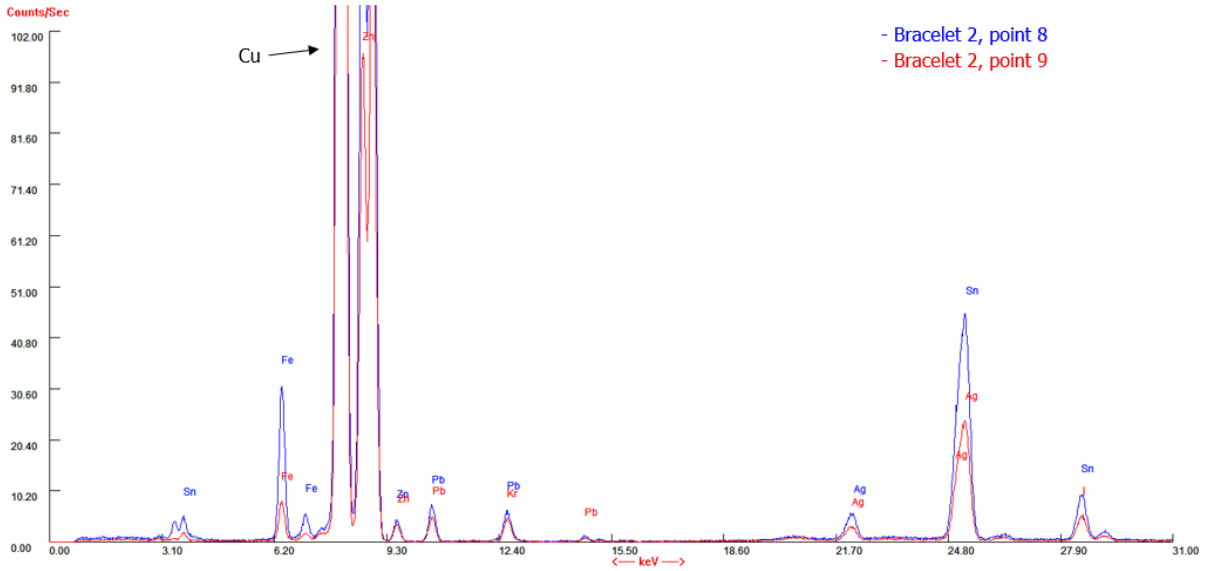


Bracelet 3

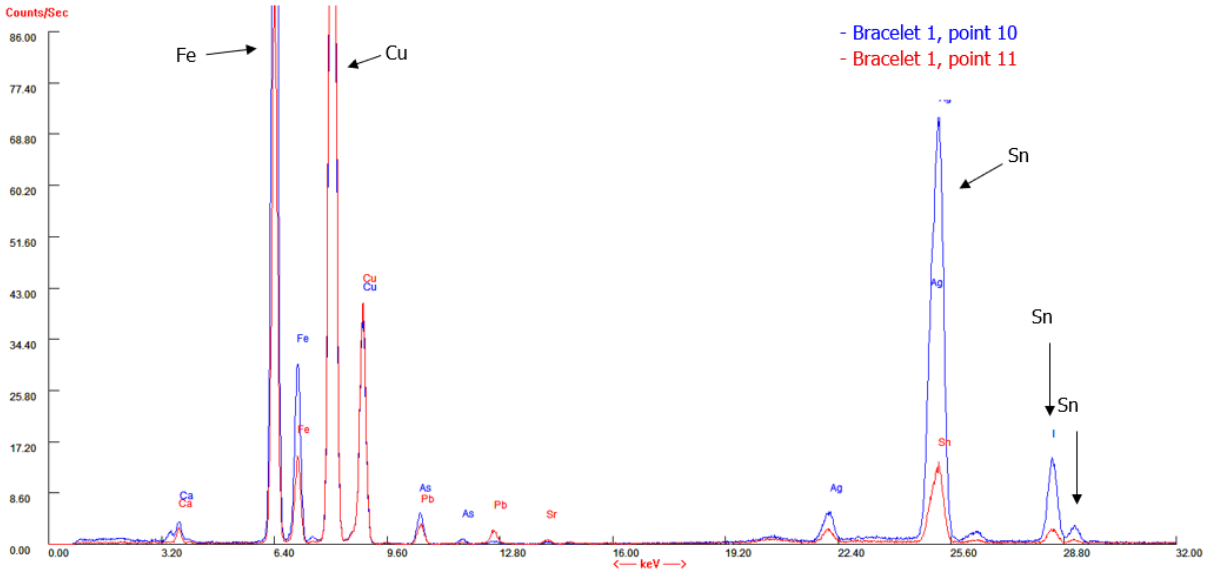


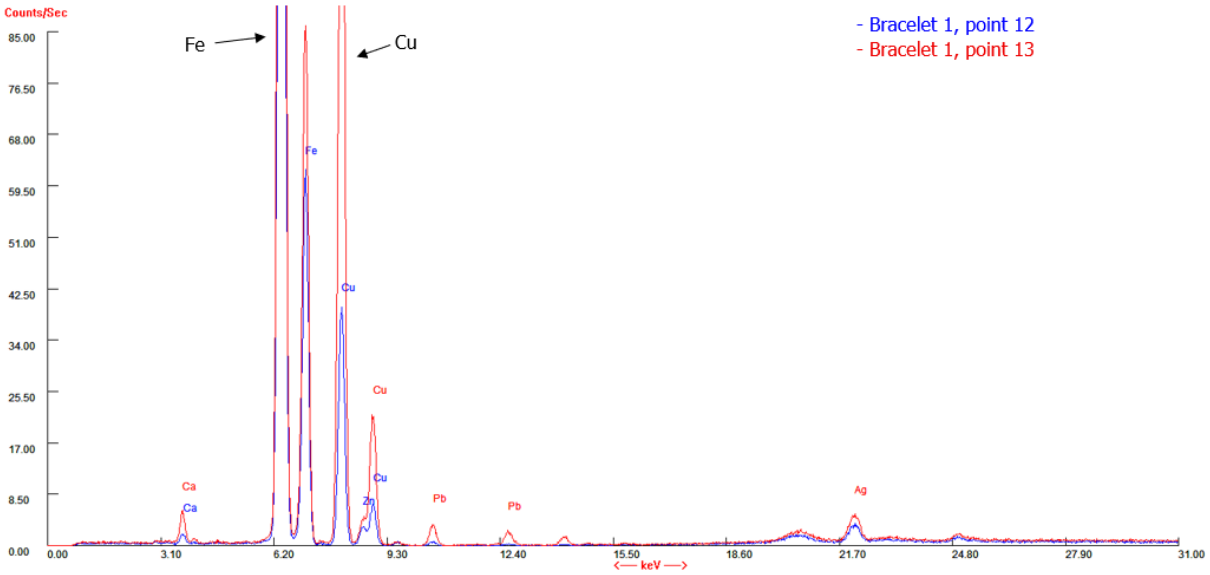
Bracelet 2



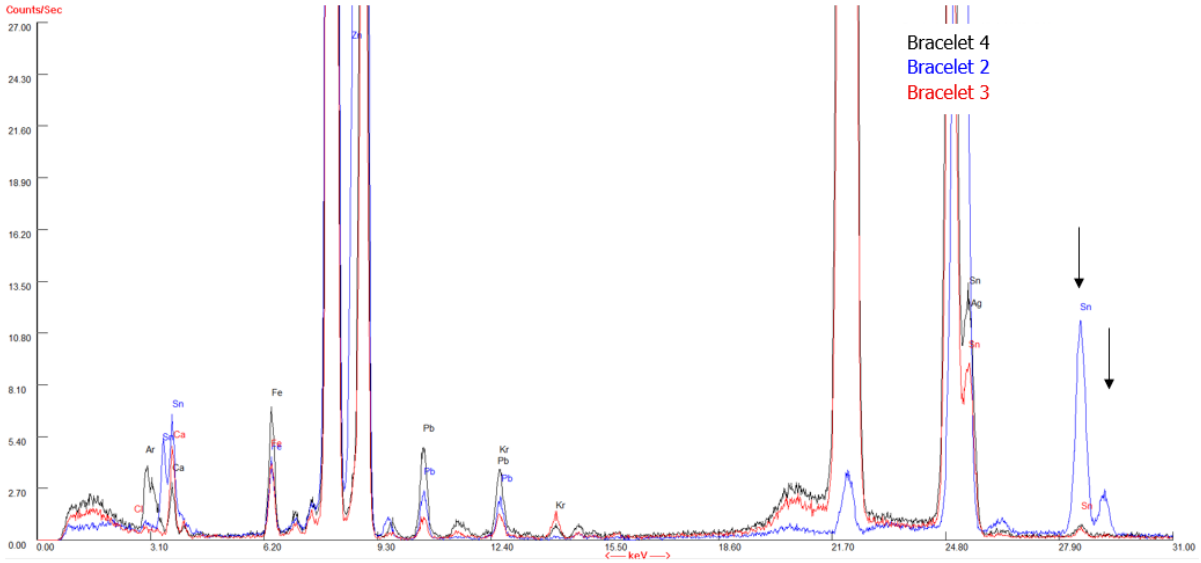

Counts/Sec
- Bracelet 2, point 8
- Bracelet 2, point 9
Cu
Fe
Sn
Ag
Pb
keV

Bracelet 1


Counts/Sec
- Bracelet 1, point 10
- Bracelet 1, point 11
Fe
Cu
Sn
Sn
Sn
Ca
As
Pb
Sr
Ag
keV



Comparison



©Christian Degrigny. Comparison of the tin ratio between bracelets 3 and 4 and bracelet 2 (in blue).

Inkwell – Rest.Nr: 2026/5944

Aims:

- To specify the chemical composition of the alloy to gain a better understanding of the metal's deterioration and to identify potential surface treatments (light grey metallic surface on the neck of the jug: silver or tin?).
- To investigate the chemical composition of several materials on the surface, such as a white deposit located on the external faces of the jug and a black deposit located on the inside.

Acquisition mode: General Metals mode (and Mining Mode for measurement 7)

Acquisition time: 60s (and 120s for measurement 7)

Measurement locations



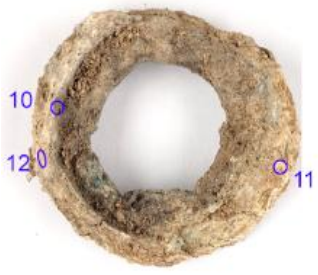
A



B



C







D E F



G

Measurement's locations: (A) the bottom of the jug; (B, C) faces of the jug; (A) the lower part (or internal part) of the lid; (E) the upper part (or external part) of the lid; (F) a fragment of white material from a face of the jug and (G) the black material found inside the jug.

Analytical data

" - " replaces "<LOD" (limit of detection) in the tabs, and important elements are highlighted.

Results were rounded to the nearest tenth.

General Metals mode

2026/5944	Nr	**Sb**	**Sn**	**Cd**	**Zr**	**Bi**	**Pb**	**Hg**	**Au**	**As**	**Cu**	**Fe**	**Ti**
Jug alloy	**1**	0,1	0,1	0	-	-	3,1	-	0,1	0,7	94,6	1,2	-
	2	0,1	0,4	0	-	-	0,93	-	0,7	0,2	97,7	0,78	-
	3	0,1	4,9	0	0	-	17	-	-	1,3	75,9	0,7	0,2
Soldering material	**4**	-	0,2	-	0,1	0,4	89,3	2	0,6	-	0,7	6,4	-
	10	0,3	5,9	0,2	-	0,3	76,1	-	-	-	14,9	1,3	0,5
	11	0,1	9,8	0,1	-	0,3	87,5	-	0,1	-	0,2	1,5	-
	12	0,1	3	0,1	-	0,4	96,1	-	-	-	-	-	-
Lid alloy	**8**	0,1	0,7	-	0,1	-	52,4	0,9	0,29	-	42	3	-
	9	0,1	0,7	-	0	-	5,9	-	-	-	89,4	3,1	0,3
White material	**5**	0,1	0,1	0,1	-	0,3	98,8	-	-	-	0,1	0,2	-
	13	0,1	0,1	0,1	-	0,3	95,8	-	-	-	0,5	2,7	-
Black mat	**14**	-	0,6	-	0,2	0,5	41,2	8,5	-	-	34,5	14,3	-

	15	-	1,1	-	0,2	0,5	26,1	12,7	-	-	52,1	7,3	-

Mining Mode

	Nr	**Bi**	**Pb**	**As**	**Cu**	**Fe**	**Bal**	**Y**	**Sr**	**Rb**	**Ca**	**K**	**Cl**	**Si**	**Mg**
White material	**7**	0,6	48,8	48	0	0	-	0,3	0,1	-	0,3	0,2	-	0,7	-
Black material	**17**	0	1,8	1,1	4,1	0,9	75,5	-	0,1	0,2	8,4	0,5	0,1	4,9	0,7

The **jug** seems to be made of a copper-rich alloy (up to c. 97% Cu (1 and 2)). A third measurement (3) revealed higher concentrations of tin and lead. But as the measurement was made near the edge of the jug where the solder was. The **soldering material** is made of lead and contains a high content of tin (10,11,12). These elevated values are likely attributable to the presence of the soldering material. Iron, arsenic, antimony, and manganese are trace elements in the copper ore (Bougarit and Mille, 2014, p. 107). The last element may come from the soil, such as calcium, showing up on the spectra. A silver peak is a detection error related to the device. It's visible on the next spectra too.

The lid is made of a thin sheet of copper alloy (upper part) on a thicker one of lead alloy (lower part). The distinction between the composition of the soldering material and the lead sheet is difficult.

The **soldering material** is made of lead and a bit of tin. Another measurement shows a high content of copper (10), which is probably the result of contact between the soldering material and the jug. Another one revealed a high content of iron and mercury (4) that may be explained by a contamination of the area by the **black material** inside the jug, which produced similar analytical results (14, 15). Bismuth is an element present in the lead ore, difficult to get rid of during the metallurgical process (Baron et al, 2014, p.189).

The **lid** was probably manufactured from a similar alloy to that used for the jug. However, the presence of **soldering material** and the **black material** inside may have affected the results

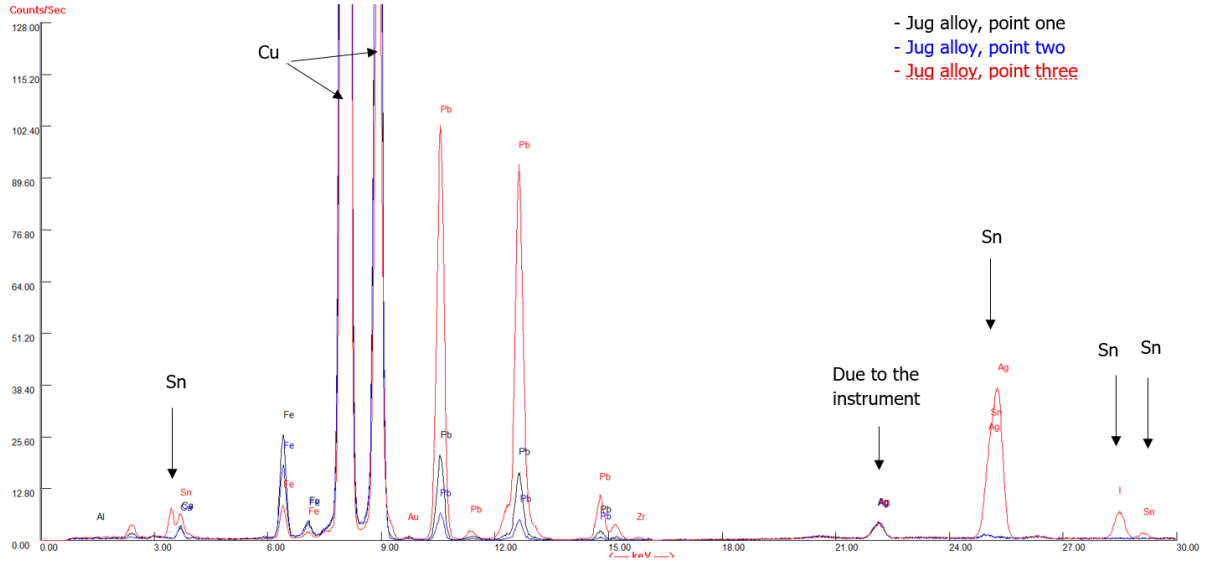
relating to the lead and iron content. It can nevertheless be suggested that the copper part of the lid is made of a high-copper-content alloy, or maybe just copper.

The analysis confirms that the **white material**, which is probably wood or plant-based organic material, was preserved thanks to lead corrosion products through mineralisation (c. 95 to 98% of lead measured). The iron detected must come from the soil or the black material. The Mining mode shows a high amount of lead and arsenic in this material.

The **black material** produced some interesting results. It could be the remains of an ink, and we wondered about the presence of iron, which could indicate whether iron-gall ink was used. We do have a result showing a high iron content. The copper and the lead probably come from the surrounding elements. However, the measurements also indicated a high level of mercury, which has only been observed twice before (4 and 8). With the mining mode, silica and calcium were detected. They come from soil contamination. This material also contains high amounts of light elements (BAL: O, H). It may be traces of ink that are being investigated, or the growth of an organism such as a fungus or roots. Indeed, this material looks like a mass of botanical matter.

Spectra

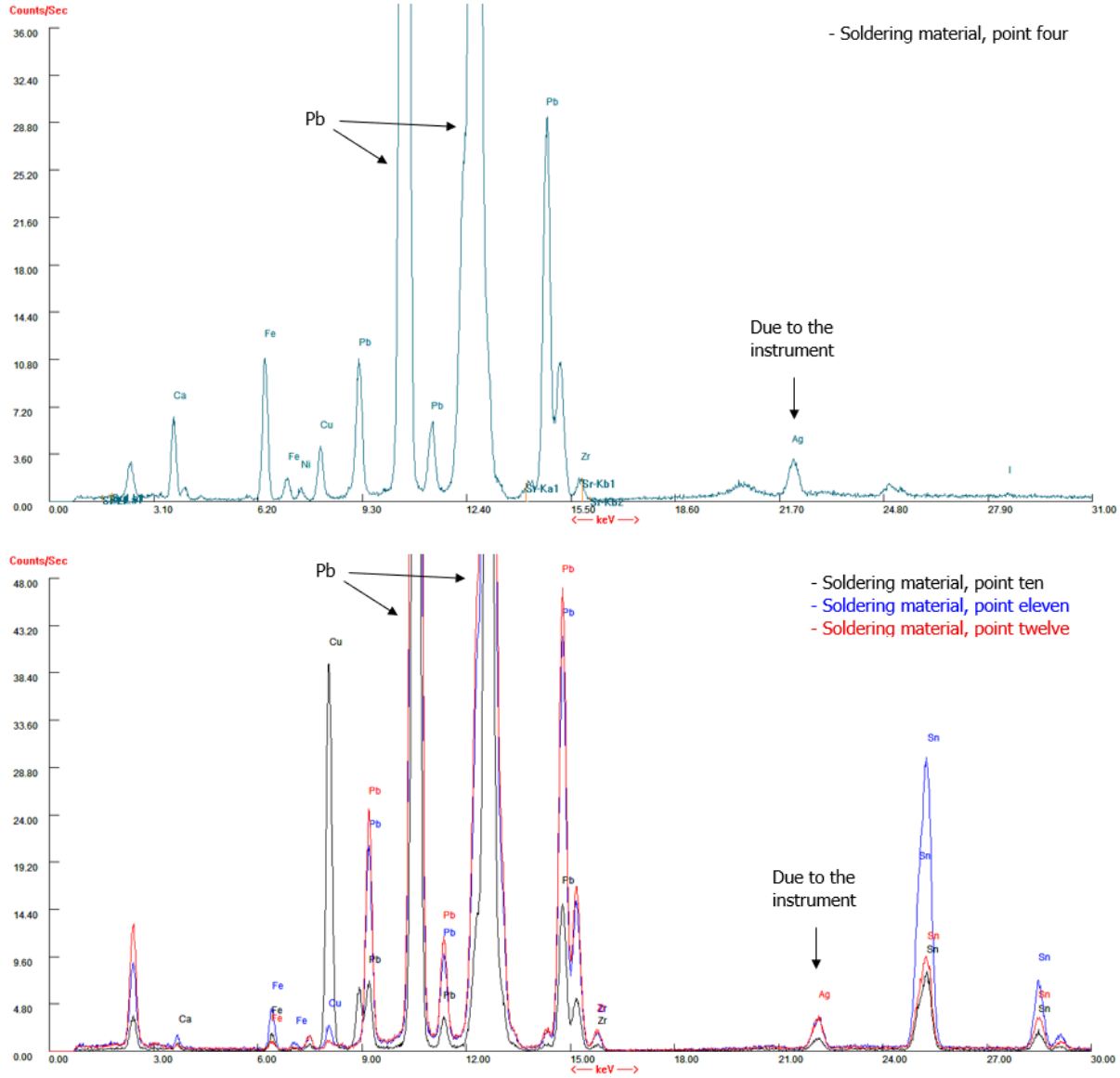
Jug alloy



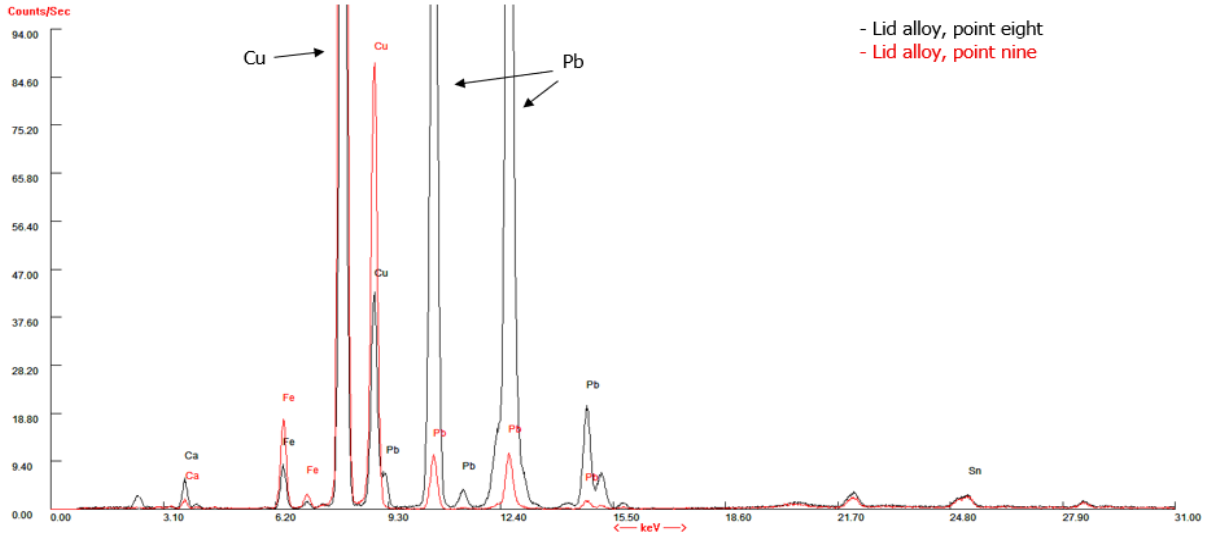
©Christian Degrigny

I = secondary Sn peaks. Interpretation error.

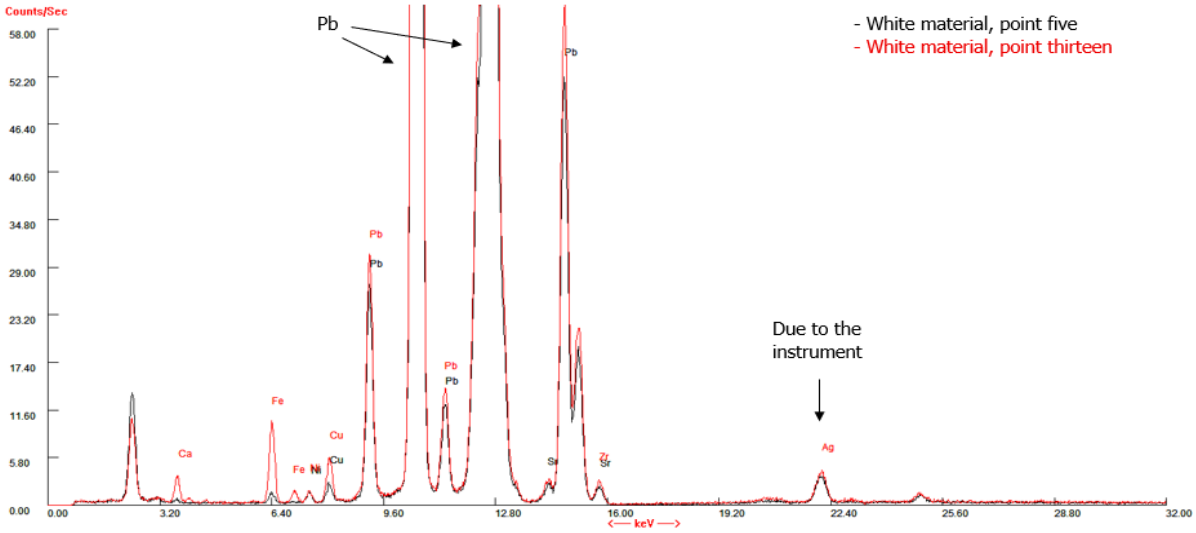
Soldering material


Counts/Sec
- Soldering material, point four
Pb
Due to the instrument
Ca
Fe
Ni
Cu
Zr
Ag
I
keV
- Soldering material, point ten
- Soldering material, point eleven
- Soldering material, point twelve
Sn

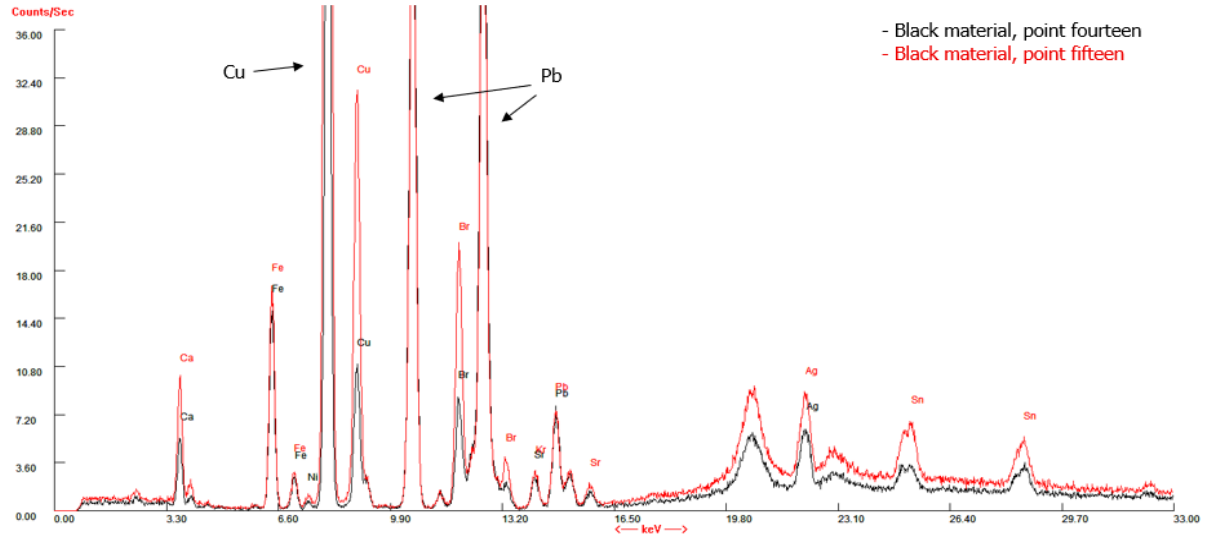
Lid alloy



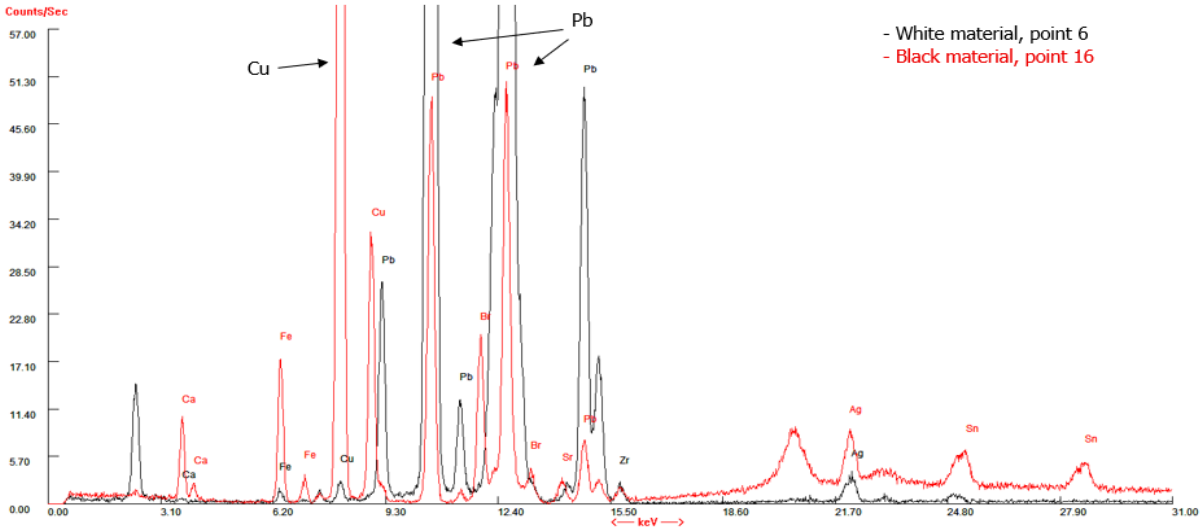
White material



Black material



Mining soil – Black and white material



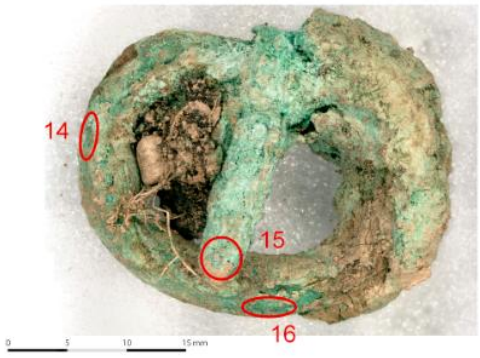
Buckle – Rest.Nr: 2026/5945

Aims: To specify the chemical composition of the alloy to gain a better understanding of the metal's deterioration and the mineralisation process of the mineralised organic material.

Acquisition mode: General Metals mode

Acquisition time: 60s

Measurement locations



Analytical data

" - " replaces "<LOD" (limit of detection) in the tabs, and important elements are highlighted.

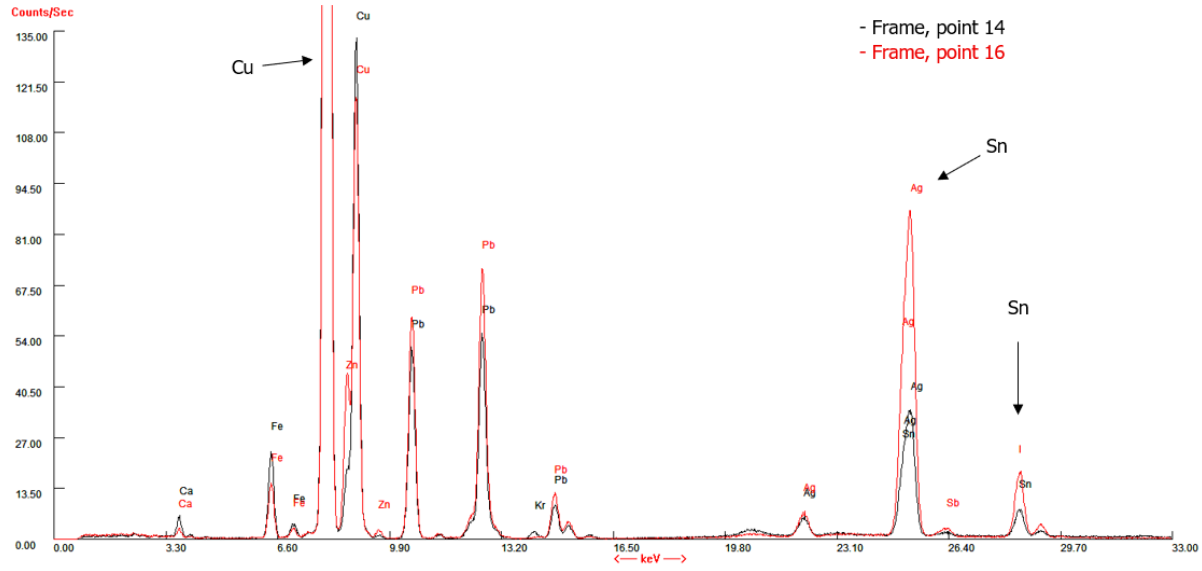
Results were rounded to the nearest tenth.

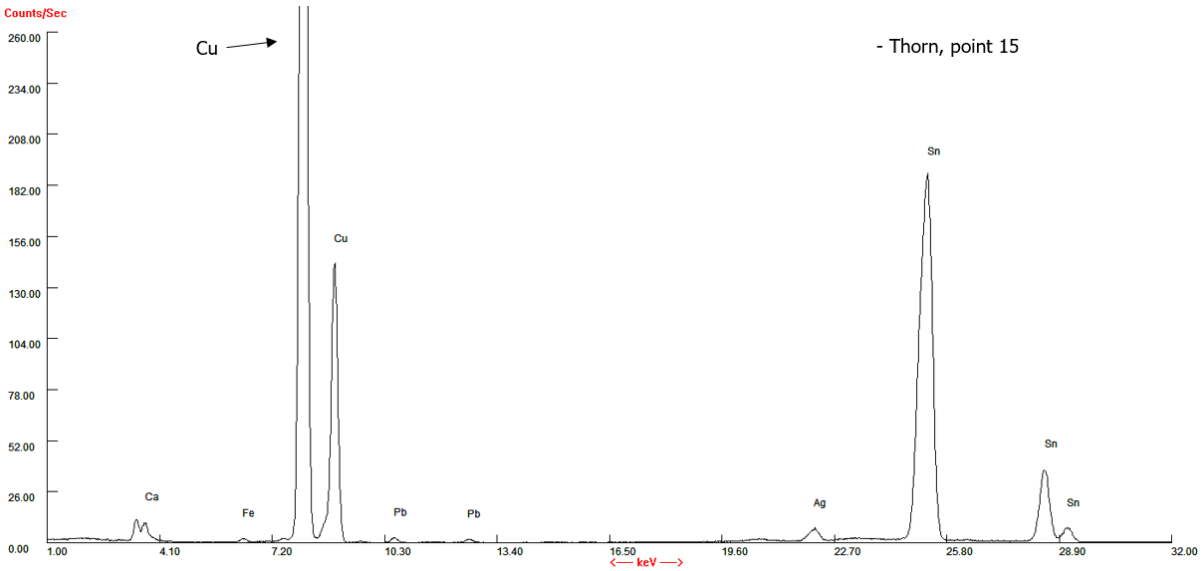
2026/ 5945	Sb	Sn	Bi	Pb	Hg	Zn	Cu	Fe	Ti
1	0,2	5,6	0,1	13,2	0,2	1	76,4	2,9	0,2
2	0,1	24,8	-	0,3	-	0,4	74	0,1	0,2
3	0,4	12,9	0,1	14,2	0,5	2,7	66,7	2,0	-

XRF analysis confirmed the observations made during the condition survey. Alloys of the **thorn** and the buckle **frame** are different; thus are the alterations. The **thorn** is made of a copper-based binary alloy (Cu, Sn). The frame is made of a copper-based ternary alloy (Cu, Pb, Sn)

with a high iron (Fe) content (traces in lead ore). This content may come from the alloy and from the soil.

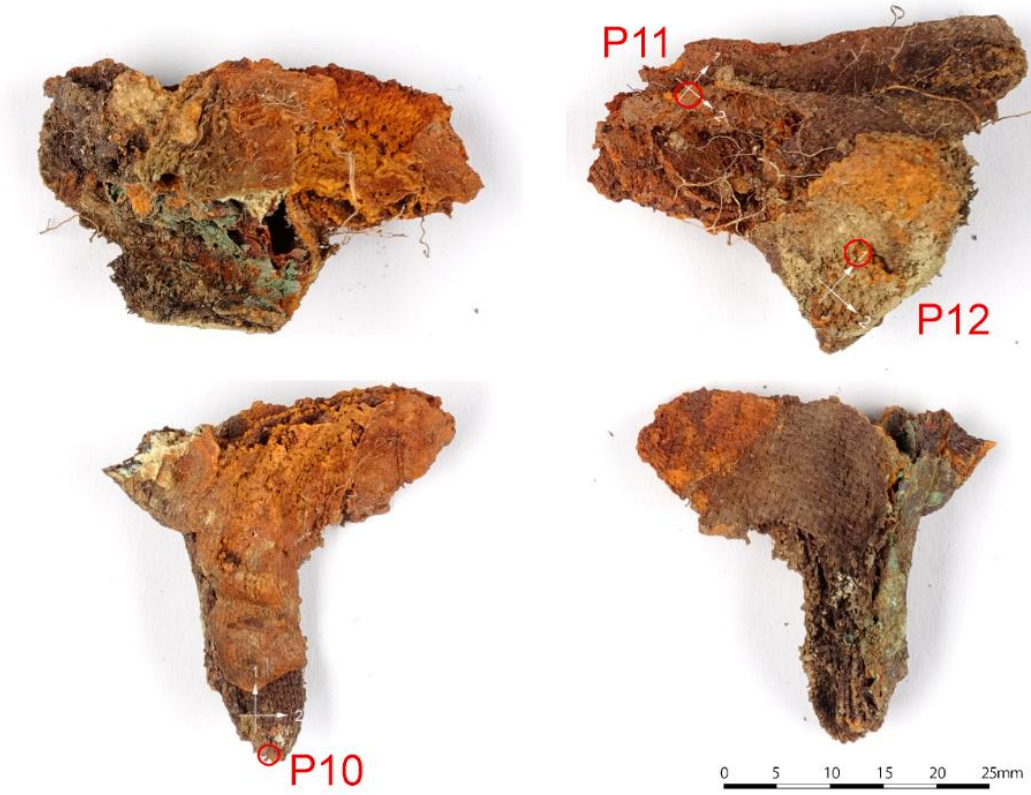
Spectra





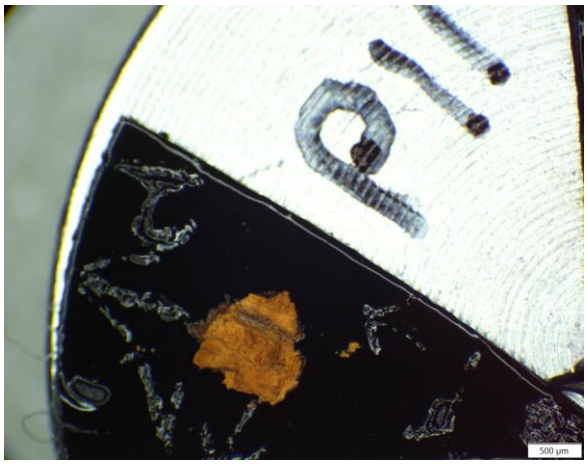
1.1.21. Samples (P = Probe (DE))

Bracelets – Rest.Nr: 2026/5943

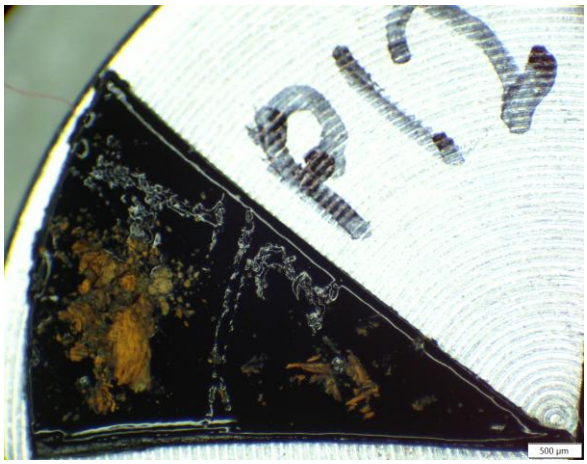




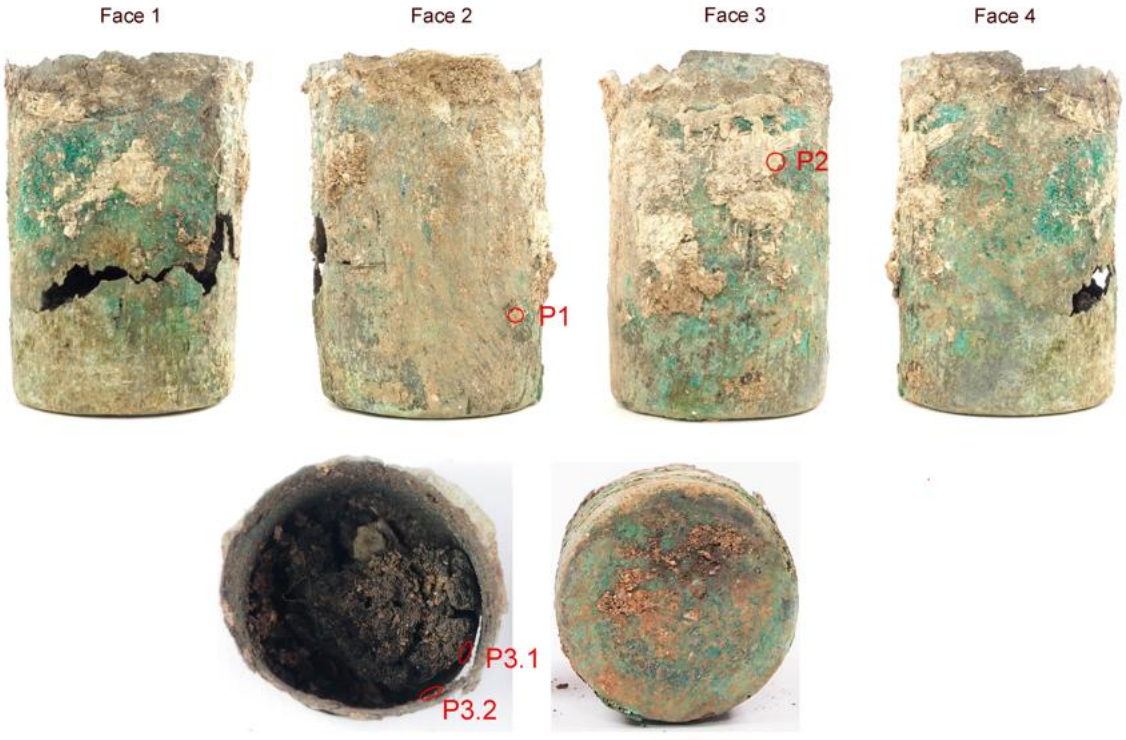

1
2
1 mm


500 µm


1
2


500 µm

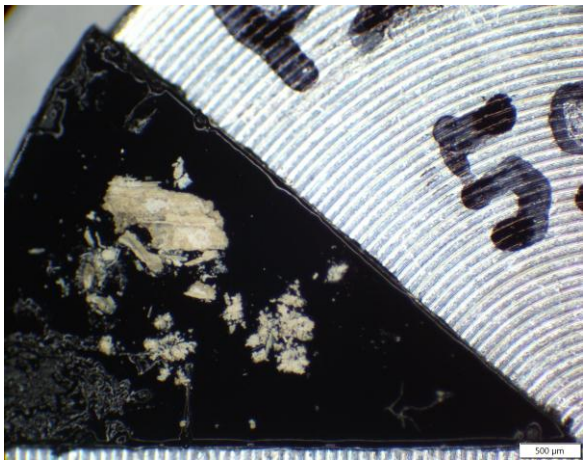
Inkwell – Rest.Nr: 2026/5944

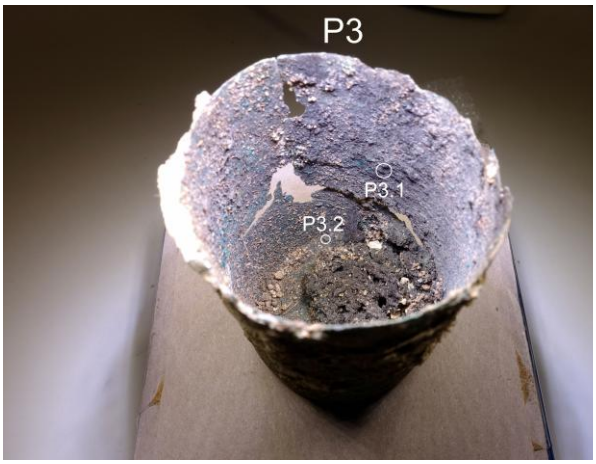


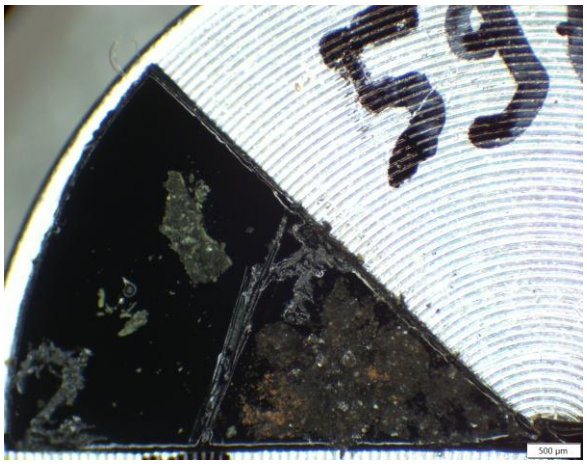


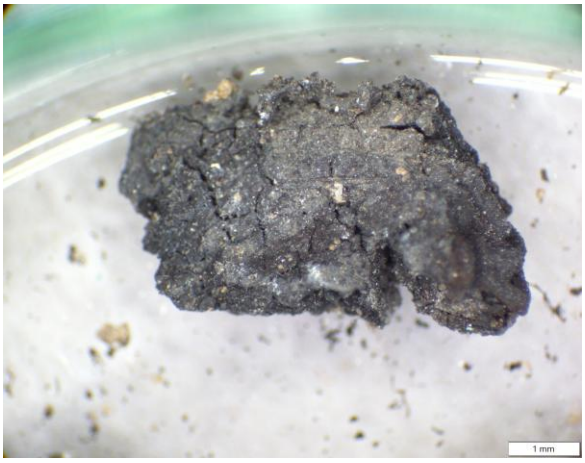


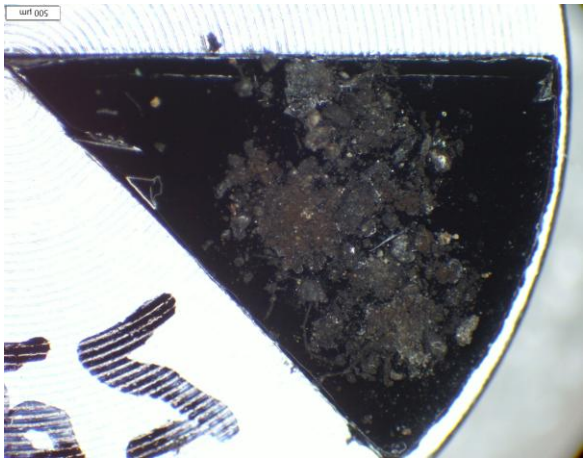

1 mm


500 µm

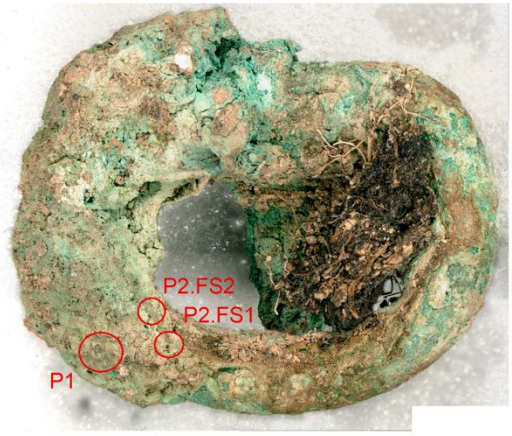

P3
P3.1
P3.2

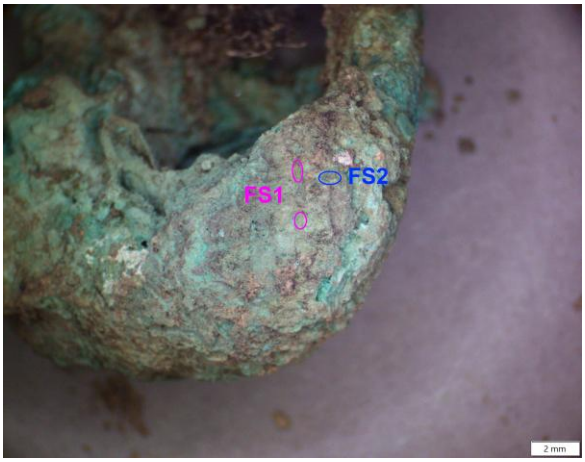

500 µm

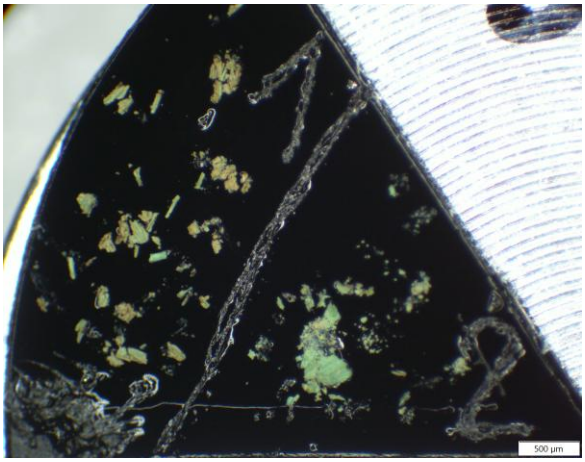

1 mm

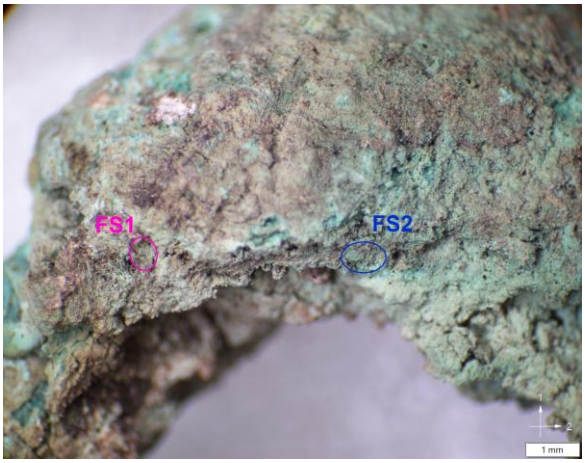

500 µm

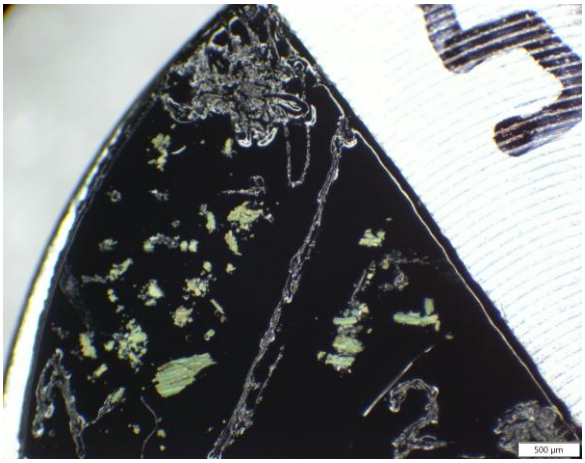
Buckle – Rest.Nr: 2026/5945











1.1.22. PLM

Technique: Polarised light microscopy (PLM) uses plane-polarised light and, when required, crossed polarisers to reveal the optical properties of anisotropic materials. Concerning bast fibre, it can help precisely identify fibres based on their internal structures. Their fibrillar structure orientation is S-twisted (flax, ramie) or Z-twisted (hemp, jute) depending on the plant. The microfibrils that make up the structure are birefringent* and change colour when viewed under polarised light, changing the angle of 90° (Haugan, Holst, 2013, p. 151-152). The results should be interpreted with caution, as they are not sufficient for a clear result but can support a hypothesis.

Tool: Leica DM 2500 P

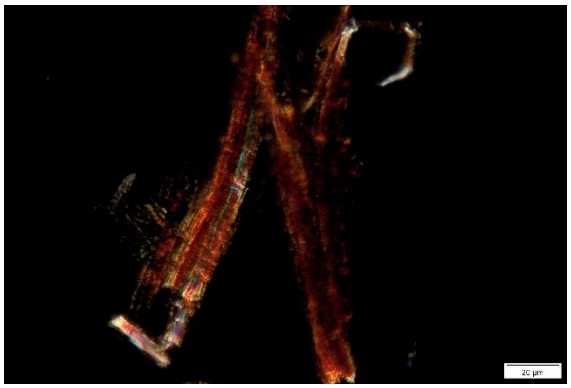
Operator: Marine Roux, Cristina Mazzola

Bracelets – Rest.Nr: 2026/5943

Aim: To identify the nature of the fibre of T1.

Result: Bast fibres (characteristic cross lines called nodes are visible). Maybe flax (Herzog test).





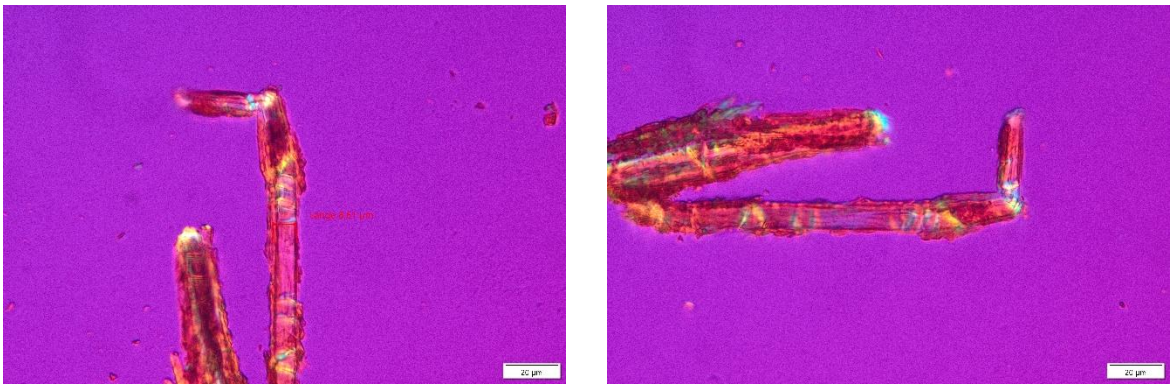


Figure 132: FS1 under the PLM, bright and dark field, and with the compensator. When rotated 90°, a section of the thread turns blue. It could be flax.

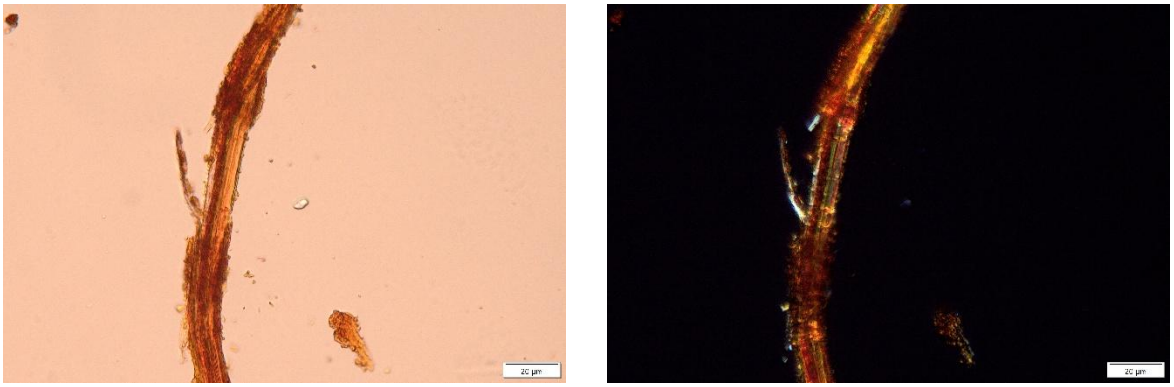


Figure 133: FS2 under the PLM, bright and dark fields.

1.1.23. SEM

Tool: Phenom ProX G7 Desktop from Thermo Fisher Scientific

Operator: Marine Roux, Cristina Mazzola

Parameters: 10 kV, resolution 2048, quality high rate, 6.0 Hz

Bracelets – Rest.Nr: 2026/5943

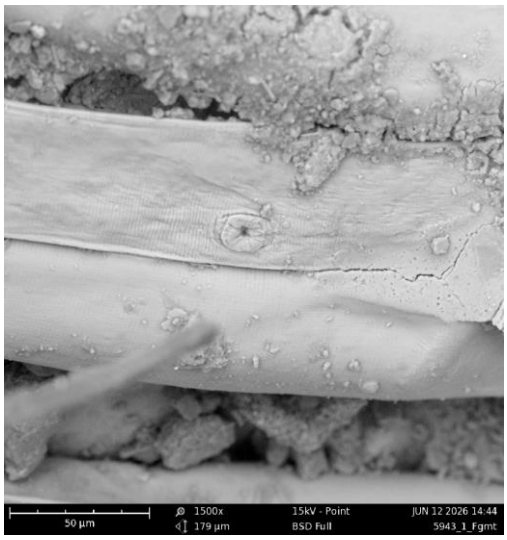


Figure 134: Nematodes in iron corrosion. Bracelet 1.

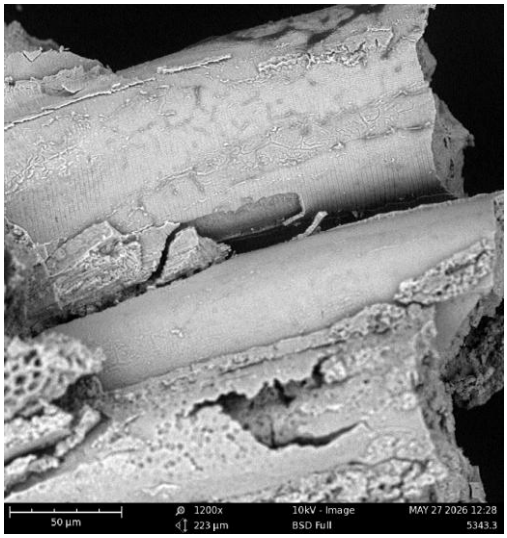


Figure 135: Nematodes in copper corrosion. Bracelet 3.

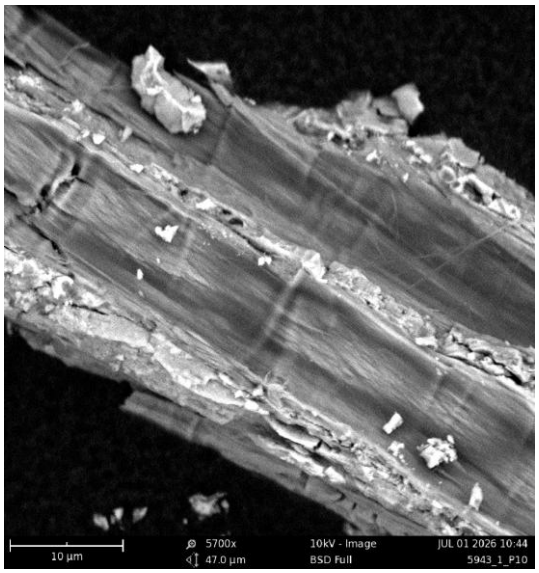


Figure 136: Negative mineralisation of bast fibres in iron corrosion. Bracelet 1.

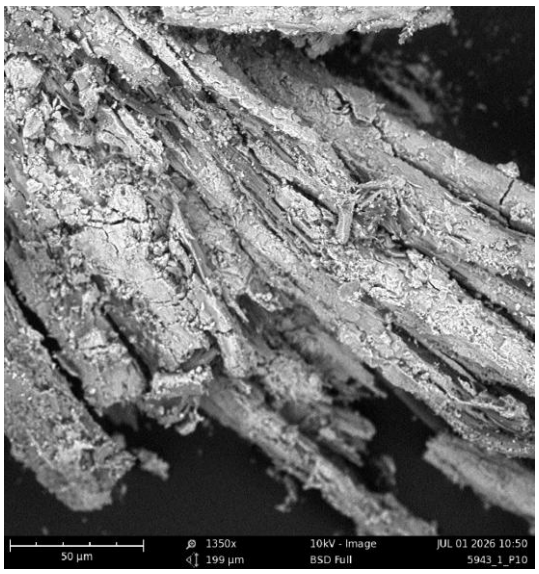


Figure 137: Positive minéralisation in iron corrosion. Bracelet 1.

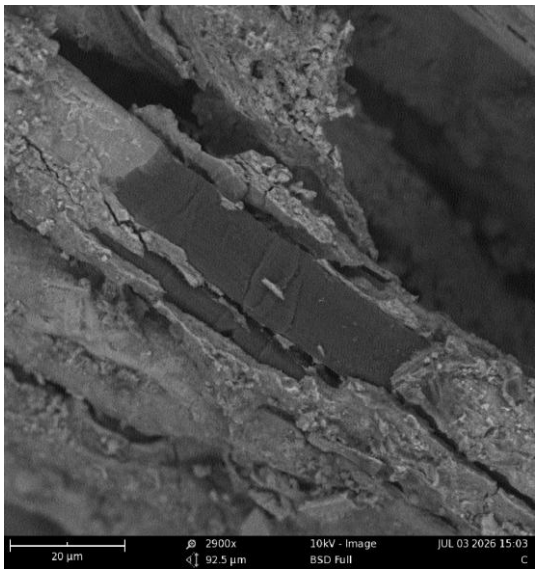


Figure 138: Superficial mineralisation of bast fibres. Fibre for the consolidant test and its consequences.

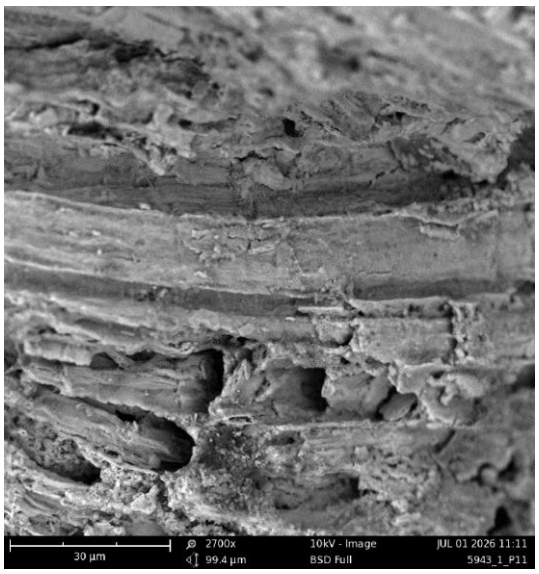


Figure 139: Negative mineralisation of bast fibres. Sample P10. Bracelet 1.

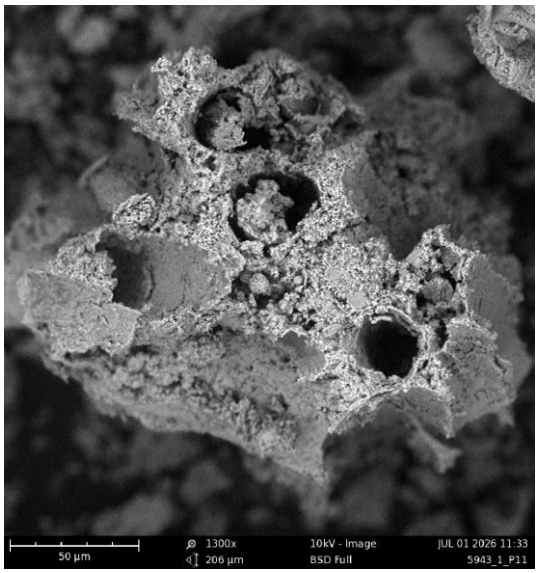


Figure 140: Partial mineralisation of animal fibre (wool?). Bracelet 1. Sample P12.



Figure 141: Partial mineralisation of animal fibre (wool ?). Bracelet 1. Sample 12. Scales visibles.

Inkwell – Rest.Nr: 2026/5944

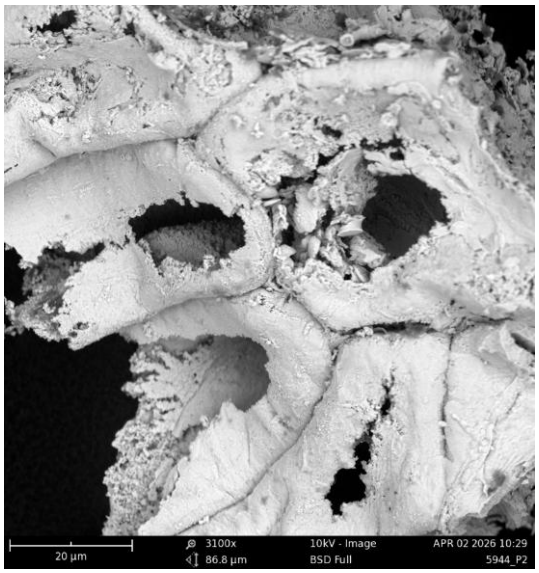


Figure 142: Mineralised wood or bast fibres with lead corrosion products.

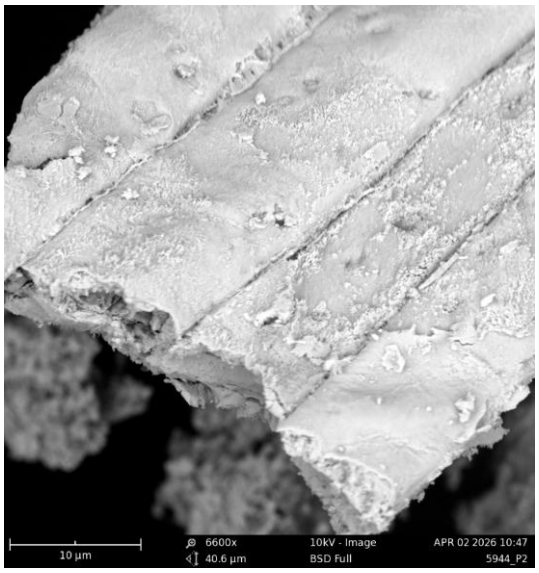


Figure 143: Mineralised wood or bast fibres with lead corrosion products.



Figure 144: Mineralised wood or bast fibres with lead corrosion products.

Buckle – Rest.Nr: 2026/5945

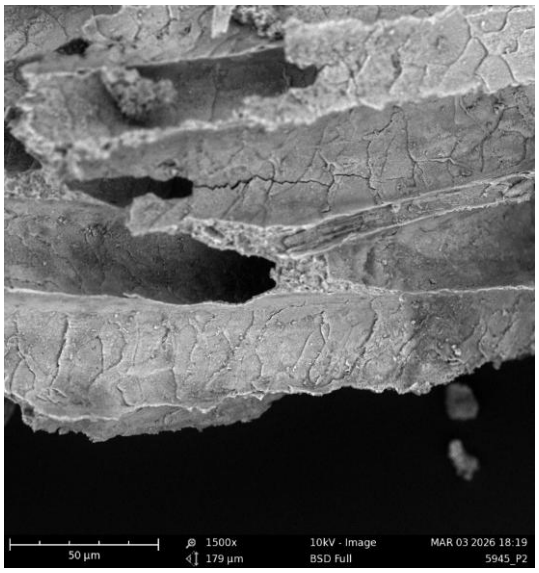


Figure 145: Mineralised animal fibres (wool?) in copper corrosion