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NON-INVASIVE METHODOLOGIES FOR THE STUDY OF MINERALISED TEXTILE TRACES IN IRON AGE CONTEXTS

1. Introduction

This paper concerns the study of mineralised textile traces preserved on the fragments of the bronze situla found at Buttrio in 1891, dated to the first half of the 7th century BC and currently conserved in the Archaeological Museum of Udine, using non-invasive methodologies. Textiles are generally rare finds in most archaeological contexts but can survive in mineralised form (Chen *et al.* 1998). Mineralised textiles are formations in which metal corrosion products form casts of or around fibres retaining their external morphology and size almost unaltered. Even when minute, such traces can provide a considerable amount of information about ancient textiles (e.g. Gleba 2017). Traditionally, they are documented and investigated using 2D documentation – drawings, macro and micro photographs, and Scanning Electron Microscopy (SEM). However, 2D documentation does not always bring out the three-dimensional structure of these remains making further analysis problematic. Conservation treatments of metal objects that preserve mineralised textile remains further complicate their analysis using traditional methods by making the object surface shiny and reducing the relief. Reflectance Transformation Imaging (RTI) (Frank 2014) and, most recently, micro-computed tomography (Karjalainen *et al.* 2023) and synchrotron microtomography (Iacconi *et al.* 2023) have been proposed as viable techniques for mineralised textile documentation. These techniques are however time-consuming and/or prohibitively expensive. The case study presented here made use of structured light scanner as an economical and fast alternative for 3D documentation of mineralised remains.

3D survey is the process of capturing and reproducing the shape and appearance of an object or scene, including colour information. It is a research area within the field of computer vision that involves multiple stages and presents open problems. The methods and tools used in the survey of Cultural Heritage (CH) vary depending on the characteristics of the object being studied, the required precision, and the intended use of the final 3D model. The survey is a complex operation both methodologically and operationally. It requires critical interpretation skills to understand the object being surveyed and to derive the correct strategies to achieve the best results (Remondino, Rizzi 2010; Brunetaud *et al.* 2012; Chiabrando *et al.* 2014; Balletti *et al.* 2014b).

In recent years, the fields of Cultural Heritage (CH) have seen great success with Structure from Motion, laser scanners (triangulation or time-of-flight), and structured light systems. These technologies have made it easier to acquire data related to the geometry and shape of both simple and complex structures (Bonfanti *et al.* 2013; Balletti *et al.* 2014a). The structured light technique is an active method that uses a projection device to project structured patterns. The digital image detector captures the scene and processes it to reconstruct the geometry from the pattern deformations. Texture acquisition accompanies this method and can yield impressive accuracy results (Salvi *et al.* 2010; Zhang 2018).

In the present study, we used different non-invasive methodologies and instruments to document and investigate four bronze situla wall fragments that preserve mineralised textile traces on their internal walls. The study aimed to: a) identify the fibres used in the production of the textiles (whether animal or plant, and if possible, the specific species); b) to determine the main textile structural parameters, including weave type, thread count per centimetre, thread twist, diameter and angle, and the presence of edges and other peculiar elements; c) to understand the manufacturing processes employed.

E.F., V.B., M.G.

2. The Buttrio find: a Nineteenth century discovery

Buttrio is a small town located in the Eastern Hills of Friuli Venezia Giulia, in the province of Udine. In this area, some findings from the Roman period are known, particularly related to the road networks that connected north-eastern Italy with the *Noricum* (modern Austria). In 1880, some pre-Roman artefacts were reported in the area for the first time, accidentally discovered during agricultural works in the Buttrio countryside. The discovery was reported by Vincenzo Joppi, a doctor, but also a librarian and a scholar of local antiquities, in a private letter to Luigi Pigorini (Visentini 2020). The following year, the Director of Antiquities and Fine Arts, Giuseppe Fiorelli, after a communication by the Honorary Inspector of Friuli, Francesco Toppo, officially published the Buttrio's discovery in the journal «Notizie degli Scavi di Antichità» (Fiorelli 1881), reporting the finds of metal objects, including pins and a bronze cup.

The most detailed description of the finds was finally provided in 1891, when Prof. Alexander Wolf delivered a batch of materials to the Museum of Udine: these materials were discovered by the Bolzicco brothers, who owned some fields in Buttrio, and corresponded to what was mentioned by Joppi and Toppo (Visentini 2020). In Wolf's letter are mentioned fragments of pins, of an axe, some buried bones, potsherds and «many fragments of

Fig. 1 – Fragments of the bronze vessel at the Restoration Laboratory, directed by Dr. Domenico Ruma (on the left) (Restoration final report L.A.A.R. S.r.l.); the reconstruction of the Buttrio situla (on the right) (Visentini 2020).

a bronze vessel» (Visentini 2020, 41). These materials were placed inside a burial pit, approximately 70 cm deep, with an initial diameter of 50 cm that gradually narrowed towards the bottom to a diameter of 30 cm. The walls of the pit were lined with rough, unfinished stones. The information available about this context is limited, making it impossible to reconstruct the original arrangement in ancient times, both in terms of the composition of the grave goods and in relation to any other burials that may have been present in the area. The fragmented state of a large part of the archaeological artefacts, especially the bronze vessel, the pins, and the pottery, suggests that the grave had been significantly disturbed by subsequent actions, likely agricultural activities.

The archival documents and materials were first re-examined by Paola Visentini in 2020. Following the completion of restoration in 2022 (Fig. 1), the complex from Buttrio is now being analysed by a broader research group (V. Baratella, M. Gleba, E. Faresin, P. Visentini, M. Cupitò), to characterise the artefacts using archaeological and archaeometric approaches, contextualising the objects in terms of their typology, chronology, and historic developments.

The bronze situla, the focus of this contribution, represents a very important link between north-eastern Italy and the Hallstatt world, particularly with Slovenia. This vessel finds a precise comparison with a situla from the Slovenian cemetery of Stična-Griže Nekropole (Jereb 2016, n. 12, tav. 11) dated to Ha C1 (7th century BC). During the restoration of the situla, textile traces were identified on the interior of four fragments. As these are the only Iron Age textile remains from this region discovered to date, a suite of diverse methods was used to carry out technological textile analysis.

V.B.

3. Methods

The purpose of technological textile analysis is to determine the culturally and chronologically relevant characteristics of the examined fabrics. Textile analysis includes identification of raw material (flax, wool, etc.); determination of structural parameters such as weave type (tabby, twill) and thread count per cm (which is indicative of textile quality); thread twist (z – clockwise; s – counter-clockwise, i – no discernible twist, *– spliced; two or more single threads can be plied, usually in the direction opposite from the twist, e.g. Z2s - two s-twisted threads plied in z direction, or S2z - two z-twisted threads plied in s direction), diameter and angle; presence of edges and any other characteristic elements, such as pattern, sewing, etc. (Fig. 2).

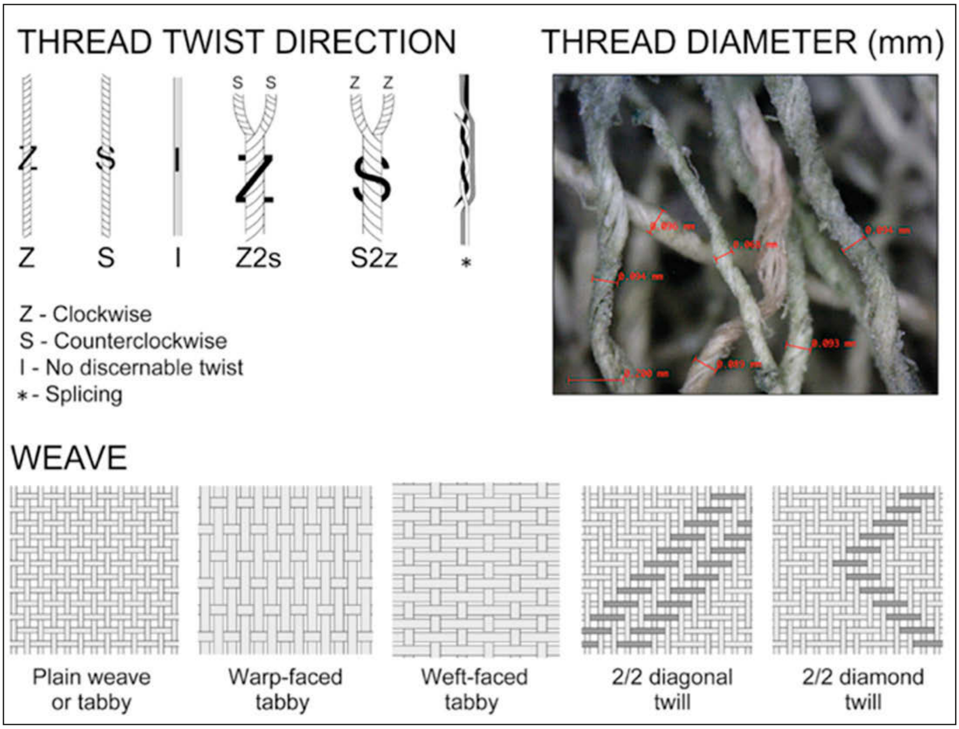

Fig. 2 – Structural parameters recorded during textile analysis (processing M. Gleba).

The study required thorough macro and micro documentation of the textile remains in 2D and 3D. The workflow developed for the study included (Fig. 3):

– Macro photographs using NIKON Z50 and NIKKOR Z 105mm F2.8 S MACRO.
– Autoptic observation and digital micro photographs with portable digital microscope Dino-Lite AM7115MZT at different magnifications (20x, 50x, 230x).
– Scanning Electron Microscopy (SEM) carried out at the Centro di Analisi e Servizi Per la Certificazione, University of Padua, using Coxem EM-30AX Plus Scanning Electron Microscope. The instrumental settings used were: backscattered electron (BSE) mode under low vacuum (LV) at 20.00kV accelerating voltage and working distance of ca. 10 mm and the fibre diameter measurements were carried out at 300x magnification.

Structured light scanning using Aurum 3D (Open Technologies, now Faro rebranded) with an accuracy of 40 μm and a camera resolution of

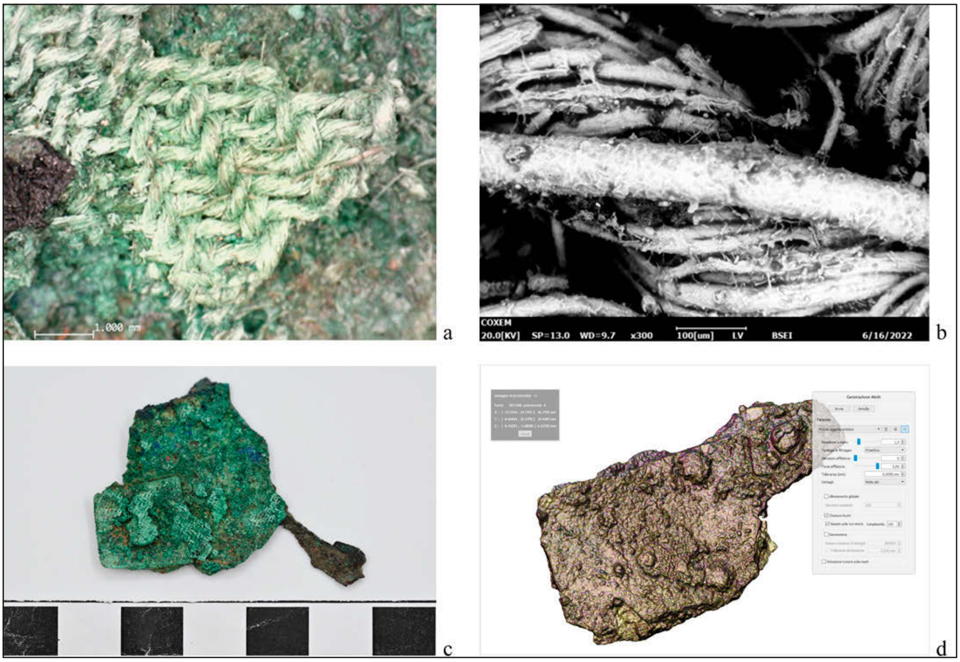

Fig. 3 – a) Close-up of the fragment showing the preservation of textile traces; b) SEM micrographs of positive fibre casts of finer and one coarse fibre; c) the macro photograph; d) the very high density point cloud acquired with a structured light scanner (processing M. Gleba and E. Faresin).

2×1.3 MPixels. The samples were acquired by taking partially overlapping range scans to produce range maps. An automatic turntable connected to the scanner and the acquisition software was used to ensure better overlapping. Each scan had a rotation angle of 32° and 11 scans were taken for each to complete the 360° rotation angle. The data collected by the scans are X, Y, Z coordinate triplets of each single point analysed. Using Optical RevEng 2.4 the acquired data was processed to create a single, complete, non-redundant and optimal 3D model using a set of range maps. The data processing was performed according to the standard steps of the 3D scanning post processing pipeline. The first stage involved aligning the range maps in a common coordinate system. This was necessary in order to ensure that all scans were accurately positioned within the overlapping area.

The pairwise ICP alignment algorithm was then employed, followed by a global registration. An automatic pre-alignment technique was applied during the acquisition phase with the objective of improving the quality of the data and verifying the quality of the acquisition in real time. The standard deviation value for fragment A was 0.0106 mm, for fragment B it was 0.0138 mm while for fragment C and D the value was 0.0109 mm and 0.0132, respectively. The range map merger (or fusion) was employed to construct a single, non-redundant triangulated mesh and in order to ensure the highest possible standards of precision, a tolerance of 0.0050 mm was set for the meshing parameters, with particular attention paid to the need to avoid any loss of quality in the definition and characterisation of the mineralised textile traces (fragment A was composed of 964699 triangles; the number of triangles in the mesh for fragment B was 1509678, for fragment C it was 1441118, and for fragment D it was 17772669). The mesh was edited to improve the quality of the computed mesh. This step requires the correction of topological mistakes, such as cross-section triangles and anomalous vertices.

E.F.

4. Results and discussion

Digital microscopy in combination with structured light scanning allowed the determination of weave type and thread structure. The 3D scans allowed close comparison of the weave in all four fragments, leading to the conclusion that they were likely in contact with the same textile. The textile on all fragments is a spin-patterned 2/2 twill. In a twill, the horizontal weft threads pass over and under vertical warps in a regular staggered pattern (in a 2/2 twill case every two threads in each system), each row being stepped to one side of the row above, creating a diagonal effect. Based on structural characteristics and overall appearance, all analysed fragments appear to have traces of the same fabric. The quality of the weave is very high, with one system (possibly warp as it is slightly less dense) 25-28 threads/cm and the other (possibly weft) 26-30 threads/cm. The textile is woven in a single spun yarn and is spin- or shadow patterned, that is woven with alternating groups of z- and s- twisted yarn alternating in both systems. This type of patterning is typical for Italy and the Hallstatt cultural area of Central Europe during the Iron Age.

SEM permitted raw material identification. Fibre casts were more or less well preserved, with variable preservation. Most are preserved as positive casts. The raw material is of animal origin, likely sheep wool, as indicated by the overall cylindrical shape of the fibres and the presence of coarse hairs. The wool appears to be of medium quality with a mean diameter of 19 µm and the coarse fibres were likely pigmented. The wool is comparable in quality to the Iron Age wools from Northern and Central Italy (Gleba 2012).

M.G.

5. Conclusion

The fabric remains preserved on the interior of the Buttrio situla likely belong to a textile used to wrap the cremated remains that were deposited inside the situla, as indicated by the charred bone remains still adhering to the fabric. The use of a wool twill for wrapping is unusual, as in most cases a linen tabby is used in a ritual that was prevalent during the Iron Age across Europe (Ruta, Gleba 2018).

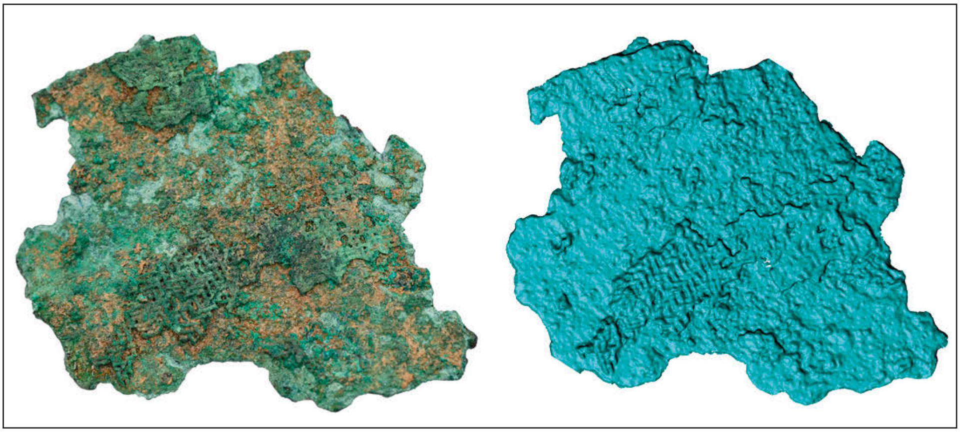

Fig. 4 – Comparison between the macro photograph (on the left) and the high-resolution 3D model (on the right) (processing E. Faresin).

The textile traces examined are made of wool, woven in 2/2 spin patterned twill using single yarn with variable twist. While the original colour of these textiles cannot be reconstructed due to their mineralised state of preservation, it is clear the fabric had a spin or shadow pattern of checks or rectangles. Spin-patterned twills are typical for Italian-Central European textile culture during the Iron Age (Gleba 2017). Twills woven in single yarn are characteristic for Italy and the Eastern Hallstatt milieu, including Slovenia and Croatia. The quality of the fabric is extremely high, demonstrating one of the highest thread counts recorded in Europe during the Iron Age, possibly reflecting the high status of the individual they were found in association with.

Structured light scanning technique and 3D models allowed a clearer view of the textile surface and visual information on overall preservation of the object, reducing interference of texture and colour during technical analysis. Moreover, it is a fast and economical method of 3D documentation for the creation of digital archives that are essential for long-term preservation of fragile archaeological remains (Fig. 4).

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REFERENCES

Balletti C., Brussa N., Gottardi C., Guerra F. 2014a, *The documentation and reintegration of a lost past*, «ISPRS Annals of Photogrammetry, Remote Sensing & Spatial Information Sciences», 2, 5, 49-55 (https://doi.org/10.5194/isprsannals-II-5-49-2014).

Balletti C., Guerra F., Tsioukas V., Vernier P. 2014b, *Calibration of action cameras for photogrammetric purposes*, «Sensors», 14, 9, 17471-17490 (https://doi.org/10.3390/s140917471).

Bonfanti C., Chiabrando F., Rinaudo F. 2013, *TLS data for 2D representation and 3D modelling. Different approches tested in the case of san Giovanni in Salluzzo (CN) Italy*, «ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences», II-5/W1, 37-42 (https://doi.org/10.5194/isprsannals-II-5-W1-37-2013).

Brunetaud X., Luca L.D., Janvier-Badosa S., Beck K., Al-Mukhtar M. 2012, *Application of digital techniques in monument preservation*, «European Journal of Environmental and Civil Engineering», 16, 5, 543-556 (https://doi.org/10.1080/19648189.2012.676365).

Chen H.L., Jakes K.A., Foreman D.W. 1998, *Preservation of archaeological textiles through fibre mineralization*, «Journal of Archaeological Science», 25, 1015-1021.

Chiabrando F., Lingua A., Noardo F., Spanò A. 2014, *3D modelling of trompe l'oeil decorated vaults using dense matching techniques*, «ISPRS Annals of Photogrammetry, Remote Sensing & Spatial Information Sciences», 2, 5, 97-104 (https://doi.org/10.5194/isprsannals-II-5-97-2014).

Fiorelli G. 1881, *Buttrio*, «Notizie degli Scavi di Antichità», 131.

Frank E. 2014, *Documenting archaeological textiles with Reflectance Transformation Imaging (RTI)*, «Archaeological Textiles Review», 56, 3-14.

Gleba M. 2012, *Tracing textiles to sheep: Investigating wool fibre development in pre-Roman Italy using Scanning Electron Microscopy (SEM)*, «Journal of Archaeological Science», 39, 3643-3661 (https://doi.org/10.1016/j.jas.2012.06.021).

Gleba M. 2017, *Tracing textile cultures of Italy and Greece 1000-400 BCE*, «Antiquity», 91, 359, 1205-1222 (https://doi.org/10.15184/aqy.2017.144).

Iacconi C., Autret A., Desplanques E., Chave A., King A., Fayard B., Moulherat C., Leccia E., Bertrand L. 2023, *Virtual technical analysis of archaeological textiles by synchrotron microtomography*, «Journal of Archaeological Science», 149, 105686 (https://doi.org/10.1016/j.jas.2022.105686).

Jereb M. 2016, *Die Bronzegefäße in Slowenien*, Prähistorische Bronzefunde, Ab. II, 19, Stuttgart, Franz Steiner Verlag.

Karjalainen V.P., Finnilä M.A., Salmon P.L., Lipkin S. 2023, *Micro-computed tomography imaging and segmentation of the archaeological textiles from Valmarinniemi*, «Journal of Archaeological Science», 160, 105871 (https://doi.org/10.1016/j.jas.2023.105871).

Remondino F., Rizzi A. 2010, *Reality-based 3D documentation of natural and cultural heritage sites-techniques, problems, and examples*, «Applied Geomatics», 2, 3, 85-100 (https://doi.org/10.1007/s12518-010-0025-x).

Ruta Serafini A., Gleba M. 2018, *Evidence of ossuary dressing in the funerary rituals of pre-Roman Veneto (Italy)*, in M.S. Busana, M. Gleba, F. Meo, A. Tricomi (eds.), *Purpureae Vestes VI*, Zaragosa, Porticos, 203-216.

Salvi J., Fernandez S., Pribanic T., Llado X. 2010, *A state of the art in structured light patterns for surface profilometry*, «Pattern Recognition», 43, 8, 2666-2680 (https://doi.org/10.1016/j.patcog.2010.03.004).

Visentini P. 2020, *Aggiornamenti sull'attività di studio e di ricerca paletnologica di Camillo Marinoni in Friuli*, in E. Borgna, S. Corazza (eds.), *Dall'Adriatico all'Egeo. Scritti di Protostoria in onore di Paola Cassola Guida*, Udine, Forum, 37-44.

Zhang S. 2018, *High-speed 3D shape measurement with structured light methods: A review*, «Optics and Lasers in Engineering», 106, 119-131 (https://doi.org/10.1016/j.optlaseng.2018.02.017).

ABSTRACT

This study presents the preliminary results of a non-invasive analysis of bronze fragments from the site of Buttrio (Udine). The analysed sample belongs to a bronze situla dating to the second half of the 7th century BC, currently preserved in the Archaeological Museum of Udine. These fragments are characterised by the presence of mineralised traces of textiles, which are relatively rare finds in this period but provide important information about the perishable materials, which represented one the most important and time-consuming economic activities of the past. The aim is to identify the fibres used in the production of the textiles, understand the manufacturing processes employed, and explore the nature of the archaeological context. The textile traces were analysed using standard analytical procedures to determine the main structural parameters, including weave type, thread

count per centimetre, thread twist, diameter and angle, and the presence of edges and other peculiar elements. The analysis has been performed with traditional 2D documentation, including macro photos, and was complemented by a Scanning Electron Microscopy to characterise the morphology of the fibres. Additionally, a morphometric analysis of the sample was conducted using a structured light scanner to obtain 3D models that allow submillimetre measurements.