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A mysterious little piece:
A compound-weave textile incorporating sea silk from the Natural History Museum, London

Abstract
Sea silk, derived from the beard of the *Pinna nobilis* clam, has often been described in historical sources, but only rarely identified scientifically in extant textiles. This paper describes the microscopy of the fibres in a textile held in the Cuming Collection at the Natural History Museum in London. The textile is a compound weave that incorporates yarns made of sea silk, ordinary cultivated silk and a fine animal coat fibre. The fibres were identified by a combination of transmitted-light, polarised-light and scanning electron microscopy. There is little documentation concerning the origin of the piece, but it is likely to be18th-century Italian and may have come from a waistcoat.

Keywords: Sea silk, *Pinna nobilis*, byssus, compound weave, microscopy, 18th century, waistcoat

Introduction (FM)
For some years now, an almost forgotten textile material has been discussed in archaeological textile research: sea silk, a product of a large species of marine bivalve mollusc, the noble pen shell, *Pinna nobilis* L. (McKinley 1998) (fig. 1). Its antique origin, its rarity, and, above all, its naturally golden-bronze colour made it a subject full of myth and mysteries. A few written sources from antiquity speak of sea silk, mainly in paraphrases or in terms not yet clarified. To this day, only one single fragment from antiquity has been found, in a woman's tomb in Aquincum (Budapest), dated to the fourth century AD (Maeder 2008). A find from Pompeii, originally identified as sea silk, turned out to be an ordinary sponge on closer analysis (Maeder & Médard 2018). The next known sea-silk item is 1,000 years later, dating to the 14th century: a knitted beret found in Saint-Denis, near Paris (for the history and production of sea silk, the biology of the *Pinna nobilis* and its byssus, and an inventory of sea-silk objects, see the project's homepage in English, Italian and German at www.muschelseide.ch).
To date, only two places where sea silk has been processed, at least since the 18th century, have been proven: Apulia and Sardinia, both in southern Italy. Various other places around the Mediterranean are mentioned in the literature (Maeder 2016b), but, as with everything that concerns sea silk, re-telling

Fig. 1: Live specimen of *Pinna nobilis* L., in the sea off Levanto, Liguria (Image: Hechtonichus, Creative Commons Licence 3.0)

of what has been heard or copies of what has been read are frequent. Dictionaries and even professional textile books are also extremely questionable sources (Maeder 2017a). On the small Sardinian island of Sant'Antioco, several weavers still process sea silk for demonstration purposes (Pes & Pes 2017). The raw material used comes from old stock.

Various species of pen shells live in almost all oceans, but the noble pen shell (*Pinna nobilis* L.) is found only in the Mediterranean, where it grows up to 120 cm tall and lives sedentarily in coastal areas up to a depth of approximately 50 m, anchored by its fibre beard in sandy soil and in underwater seagrass meadows. Once very common and sought primarily as food, populations have been declining sharply since the 1950s. The mollusc has therefore been fully protected from over-fishing since 1992. This led to a substantial recovery of the population, but in 2016 it was discovered that a protozoan parasite *Haplosporidium pinnae* sp.nov. was spreading through the Mediterranean and causing mass mortality of *P. nobilis* (Martinovic et al. 2019). The source of sea silk is therefore once more under very serious threat.

The fibre beard, zoologically named byssus, consists of thousands of fine filaments, up to 20 cm long, formed from the secretion of the glands in the foot of the mollusc. These harden on contact with the

Fig. 2: Textile fragment from the Cuming Collection, Natural History Museum, London, turned to a window so that it catches the light (Image: © ASLab)

Fig. 3: The whole fragment viewed from the front. Scale in mm and cm (Image: © ASLab)
Fig. 4: The whole fragment viewed from the back. Scale in mm and cm (Image: © ASLab)
Fig. 5: The whole fragment, edges unfolded, viewed from the back. Scale in mm and cm (Image: © ASLab)

water and anchor the shell in the ground with fan-like adhesive surfaces. The shells are brought up whole, for processing on land. The filaments, once removed from the shell, are then cleaned, washed, carded and spun by hand and then made into small accessories.

The Latin term byssus – derived from the Greek βυσσος – meant fine linen in antiquity (Maeder 2017a). The term is known from the *Old Testament*, and also from some Greek texts written on papyri or carved in stone. In ancient Egypt, priests and statues of the gods were dressed in byssus, and mummies were wrapped in it. In the 16th century, natural scientists called the anchor threads of *Pinna* and other bivalves byssus – due to a misinterpretation of Aristotle's *Historia animalium*. Here the double meaning of the term started: since textiles were also produced from the byssus of the noble pen shell, called sea silk, many believed that the term byssus already referred to sea silk in antiquity. The result of this ambiguity is found in many encyclopaedias and, in recent years, especially through mass and social media (Maeder 2016a, 2017a, b).

One of the reasons for the ignorance about this precious material – beside its rarity – is the fact that nearly all of the more than 80 objects identified to date are housed in natural history collections, often displayed together with the shell, and not in textile collections as might be assumed (Maeder 2009). Women's and men's gloves are the most common sea-silk items. Various sea-silk objects can be found in the Malacology Section, Life Sciences Department of the Natural History Museum, London. Beside one pair and two single gloves, there are two pieces of textile: a fur-like one, and one labelled a "small fragment of twill-woven fabric with felt backing". Not much is known about this last item, its date, provenance or function. The annotation "Cuming" refers to the Englishman Hugh Cuming (1791-1865), "Prince of collectors" as he was named by his biographer, S. Peter Dance: "Among 19th-century men of action few contributed as much to the material advance of natural history" (Dance 1980, 477). His main interests were in conchology and botany, collecting especially in South America and the Philippines. After his death, a great part of his collection was bought by the Natural History Museum. The small textile fragment to be described in this paper was one of them (fig. 2).

The textile fragment (PWR)

The textile was provided by the Life Sciences Department of the Natural History Museum (London) for analysis at The Anglo-Saxon Laboratory in York. It arrived in a small cardboard box with an internal printed label which read: "Cloth woven from byssus threads of *Pinna nobilis* □ Mediterranean □ H Cuming Colln. □ Acc. No. 1829 □ Reg.No: 20040207". Inside the box was a single fragment of textile packed in tissue paper. Both faces of the fabric proved to be covered in a "bloom" of white cotton fibres, which suggests that it was packaged in cotton wool at some stage. The textile is a rectangular fragment, measuring 82 mm by 40 mm, with two adjacent stitched edges folded inwards; and two other edges which have been cut (fig. 3 and fig. 4). The folded edges have been turned in by 8 mm to 11 mm and, when unfolded, the fragment measures circa 90 mm to 95 mm by 50 mm (fig. 5). There is silk stitching along the short edge and empty stitch holes along the fold of the long edge.

The textile is 1.5 mm thick and, since front and back are visually quite different, it gives the impression of two textiles layered together. Examination with a binocular microscope at x 10 magnification, however, showed that it is in fact a compound weave which has been "soft-finished" on the back. It was made from yarns of three different fibres, sea silk, ordinary silk (from *Bombyx mori*) and a very fine animal coat fibre (see below). The exact structure of the weave could not be determined, due to the heavy matting of fibres, but it is some form of double-faced twill, with the silk yarn running in one direction and the sea silk and animal-fibre yarns in the other. The sea silk dominates on the

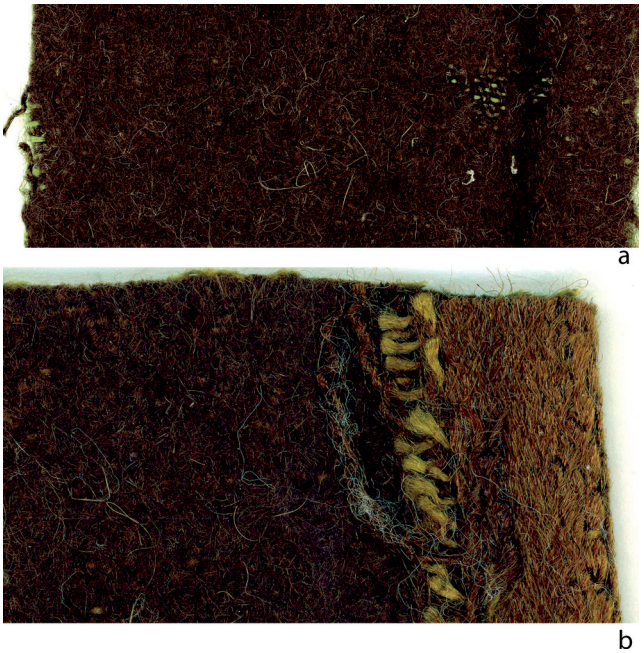

Fig. 6: a) Close-up of back of textile showing crossways silk yarns; b) Close-up of folded-back edge of textile, showing crossways silk yarns. The white fibres adhering to the surface are cotton (Images: © ASLab)

front of the fabric and has the appearance of a long velvet-like pile, although, since the textile is very worn, it is possible that the apparent pile in fact represents the broken stumps of a floating yarn. The animal fibre dominates on the back and has been "soft-finished" to give a felt-like appearance. The *Bombyx* silk yarn, only visible at the cut edges and in worn patches on front and back, binds the sea-silk and animal-fibre yarns together (fig. 6a and fig. 6b).

This, then, can be summarised as a twill-based compound weave with a soft-finished reverse. All yarns are Z-spun and single. Counting threads accurately was difficult, but there appeared to be approximately 24 sea-silk yarns and 12 silk yarns per cm. The animal coat fibre yarns could not be counted but they are at least as densely set as the sea-silk ones. The sea silk is light golden brown, the silk is its natural pale straw colour, but the animal coat fibre is an even mid-brown and may have been dyed.

The stitching

The stitching visible inside the short folded end has been worked in plied silk yarn, twisted Z2S (i.e. two Z-twist yarns have been plied together in the S-direction), circa 0.6 mm thick (fig. 7). It appears to have been dyed red, although it would be impossible to sample it without causing damage to the integrity of the piece. The stitching looks to be the remains of a running stitch, which will have attached this piece to another element. The stitch-holes along the longer edge represent the remains of a similar seam. Together, they indicate that the fragment has come from a garment or soft furnishing.

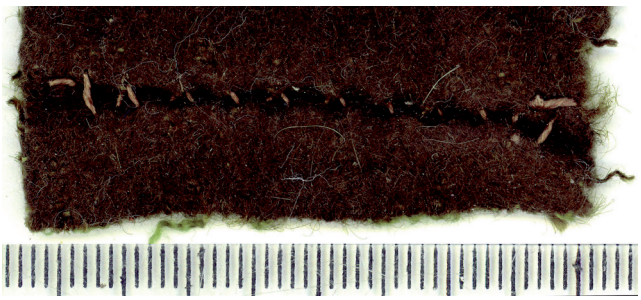

Fig. 7: Close-up of silk stitching along short edge, viewed from inside. Scale in mm and cm (Image: © ASLab)

Fibre identification

Samples of 50 to 80 fibres from each of the three yarns and the sewing thread were removed with tweezers. They were mounted on glass slides in tap-water and examined first with a microscope that has incident light at magnifications between x 40 and x 160; transmitted light at x 40 to x 640; and a measuring facility in the form of an eyepiece graticule at x 40 to x 400 (pre-calibrated with a stage micrometer). The mount was then viewed with a polarised light microscope which uses transmitted light at x 40 to x 400 and a rotating stage. Cross-sections were prepared in an acetate-based medium, sliced with a hand-held razor and viewed with the same microscopes.

Sea silk

The distinctive glistening fibres of the yarns that dominate on the front face, under the microscope were clear, plain and wide (fig. 8a). Diameters recorded

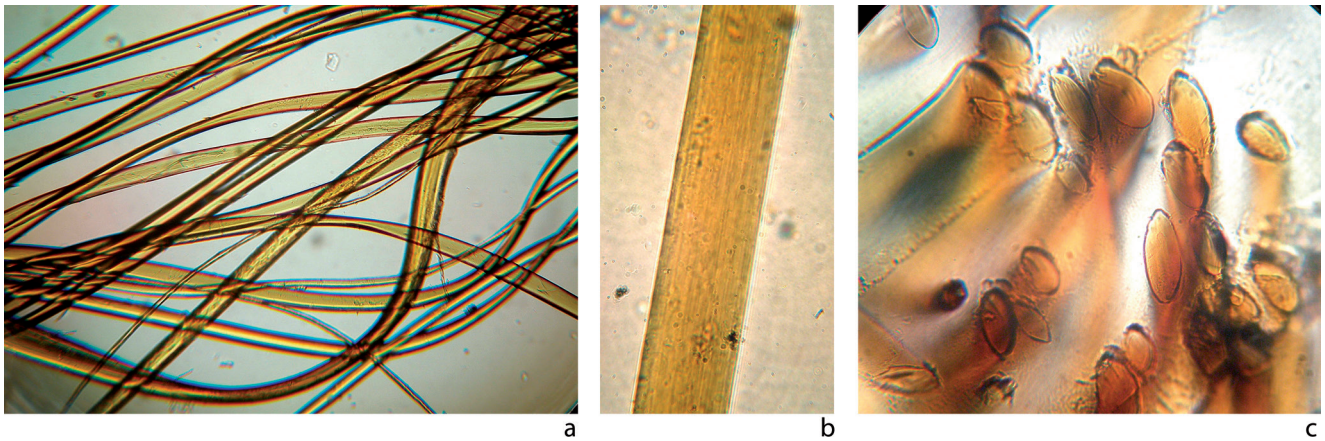

Fig. 8: a) Fibres extracted from the sea-silk yarn, viewed with a transmitted-light microscope. Note how the wide filaments appear narrow when viewed from the side. Image captured at x 40 magnification with camera zoom. Range of fibre widths in this image, 35 microns to 62 microns; b) A single fibre extracted from the sea-silk yarn, viewed with a transmitted-light microscope. Image captured at 100 x magnification, with camera zoom. The fibre is circa 60 microns wide; c) Cross-sections of fibres extracted from the sea-silk yarn, viewed with a transmitted-light microscope. Image captured at 100 x magnification with camera zoom. The fibres are in this image are 22 microns to 63 microns wide (Images: © ASLab)

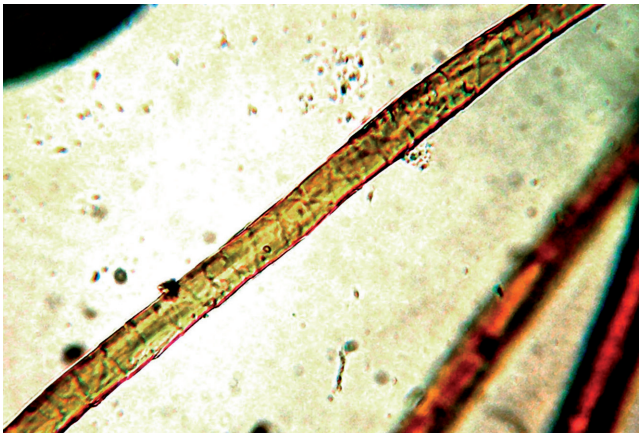

Fig. 9: A single fibre extracted from the animal-coat-fibre yarn, viewed with a transmitted-light microscope. Image captured at 100 x magnification and digitally enhanced to improve the poorly preserved scale pattern (Image: © ASLab)

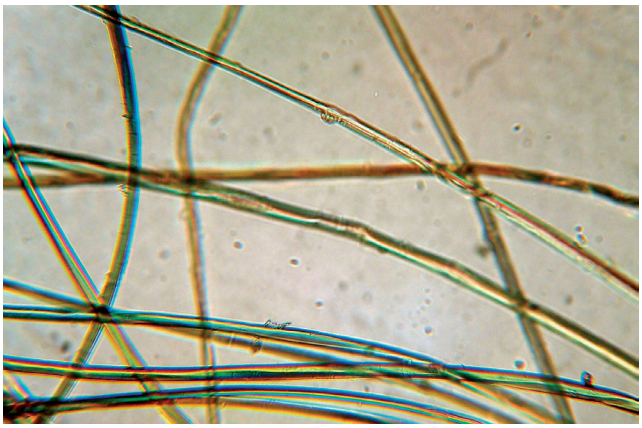

Fig. 10: Fibres extracted from the *Bombyx* silk yarn, viewed with a transmitted-light microscope. Image captured at 40 x magnification, with polariser inserted (© ASLab)

for 56 fibres ranged from 22 microns to 63 microns (mean 38.3±9.6, mode 37, median 37.1, symmetrical distribution). This can be compared with the range of 10 microns to 60 microns reported by Sicken (2017, 23). The absence of measurements below 20 microns in the current examination may result from the measuring procedure, which allows a view of the full length of the filament and to reject wide flat fibres which have rotated to present a thin sideways view. Very fine lengthways markings were visible at high magnification, but apart from this there were no internal or external features (fig. 8b). The fibres were dark when viewed with polarised light, with very little brightening as the stage was rotated. The cross-sections were uniformly elliptical (fig. 8c) (as recorded in Sicken 2017, fig. 3.4).

Fig. 11: SEMicrograph of the sample, Z-twisted thread (Image: © Margarita Gleba)

Elliptical cross-sections are also found in the fur of aquatic mammals such as the harbour seal, although those fibres have an additional pattern of overlapping scales in the cuticle (Appleyard 1978, 24-5, 105-6). The ends of the sea silk fibres were fractured and splintered, probably from wear. As this was an important finding, a sample of yarn was passed to Margarita Gleba for Scanning Electron Microscopy (SEM) and comparison with a modern specimen (see below).

Animal coat fibre

The fibres of the soft-finished reverse of the textile had the remains of a cuticular scale pattern which indicated that they were animal coat fibres such as wool or cashmere (fig. 9). Much of this scale pattern had worn away and there were many "brush end" fibres, indicative of extensive wear. The damage meant that the fibre could not be identified by species, although the very narrow diameter range of 12 microns to 17 microns would be consistent with cashmere, or perhaps fine wool extracted from sheep's fleece by some process such as combing. No pigmentation granules were present, indicating that the original (inherent) colour of the fibre was a natural white.

Bombyx silk

The fibres of the crossways yarn (fig. 10) were smooth and fine, 9 microns to 11 microns wide, with no visible internal features, and they had triangular cross-sections. The dominant colour when the polariser was rotated was blue. These features indicate degummed silk from the cocoon of the silk moth, *Bombyx mori* (Textile Institute 1975, 12-13, 69-71). There were no particular indications of wear in this yarn.

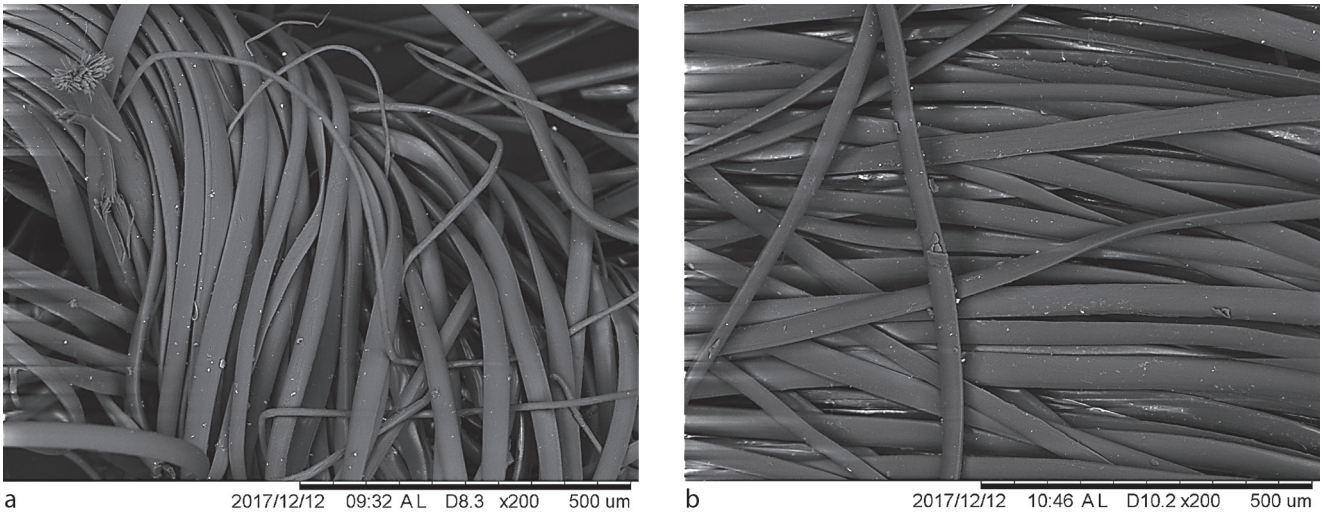

Fig. 12:.a) SEMicrograph of the fibres showing smooth surface with some longitudinal striations; the finer fibres mixed in at irregular angles are fine animal coat fibres, probably from the one of the other yarns in the textile; note the fractured and splintered fibres in the top left; b) SEMicrograph of modern sea-silk reference sample (Image: © Margarita Gleba)

Sewing thread

The fine filaments of the sewing yarn were also degummed *Bombyx* silk, as described above, although they were more irregular in profile and had some fine fibrils emerging from the fibre walls, which suggests either a low-grade silk or perhaps intense wear (Textile Institute 1975, fig. 42). This yarn appeared to have been dyed red.

Cotton contaminants

The white fibres adhering to front and back of the textile were identified as cotton (from the seed boll of *Gossypium* sp), from the twisting nature of the fibres, the prominent lacunae and the presence of fine spiral markings, which were only visible when the polariser was inserted and rotated (Textile Institute 1975, 14, 74-75).

Scanning Electron Microscopy (MG)

Further work on the sea silk fibres was carried out at the McDonald Institute for Archaeological Research, University of Cambridge. The sample was analysed using a Hitachi TM3000 TableTop Scanning Electron Microscope (SEM) in order to determine the morphological characteristics of the fibre and to acquire more detailed surface information for fibre identification. The following instrumental settings were used: analytical condition mode at 15.00 kV accelerating voltage, compositional imaging and working distance of 5 mm to 10 mm. The sample was not coated. The observed features were compared with the author's reference material of sea silk fibres, obtained from an Italian handweaver, Assunta Perilli. When observed in the SEM, the sample was a tightly Z-spun thread (fig. 11). The fibres are somewhat ribbon-like, with two broad and flat surfaces and two slightly rounded edges; they have a smooth surface with occasional longitudinal striations (fig. 12). Fine animal coat fibres are mixed in at irregular angles and probably derive from one of the other yarns in the textile (see above). Some of the fibres are fractured and splintered, likely due to wear. The flat, somewhat ribbon-like appearance of the fibres is due to their elliptical cross section (fig. 13). The diameters of 25 fibres measured a range between 11.3 microns and

Fig. 13: SEMicrographs of fibres showing an elliptical cross-section (© Margarita Gleba)

Fig. 14: Textile sample from a pattern book, "Feine Gewandschaft", dated to 1800, Monschau, Germany (Image: © Felicitas Maeder)

44.6 microns, with a mean of 27.2 microns and median of 26.6 microns. Rast-Eicher (2016, 286) provides a range of 10 microns to 30 microns for sea silk fibre, while Sicken (2017, 23) gives a broader range between 10 microns and 60 microns. All morphological characteristics of the sample demonstrate close similarities with the sea silk reference sample, which had a fibre diameter range of 11.5 microns to 52.4 microns (fig. 12b).

Conclusion (FM)

The London sea silk fragment has a twin, equally enigmatic: a small piece of fabric from a pattern book dating to around 1800, found in the once famous textile town Monschau, near Aachen in the Rhineland (fig. 14) (Maeder 2013). There was no possibility to analyse this sample from both sides, but the presence of sea silk fibres on the front has been proven (Sicken 2013). The use of sea silk in the 18th century is also known from textile entrepreneurs in Normandy (France). Such showpieces have been presented at exhibitions and fairs and offered at unbelievable prices. The *Journal de l'Empire* describes a cloth of extraordinary brilliance and beauty at the price of 500 francs for one ell (circa 70 cm) (Malte-Brun 1806). In a French textile dictionary of 1857, it reads: *"L'échantillon … dans lequel la soie de pinne-marine ne fait que le poil, c'est à-dire l'endroit du tissu, a l'aspect d'une peau de bête, d'une grande finesse, telle, par exemple, que le poil de castor"* (Bezon 1857, 316-317).

What were these two fragments used for, as thick and inflexible as they seem? Arabic texts of the 11th century tell about the *bukalamun* (besides *suf-al-bahr*, a possible Arabic term for sea silk), "a fabric with changing colours, used for saddle-cloths and for covering the royal litters" (Smith 1890; Dimand 1930; Maeder 2017c). From 18th-century travellers in southern Italy, however, it is known that sea silk was used for waistcoats (von Salis-Marschlins 1795, 509) and the luxurious fabrics for waistcoats from Monschau were famous and greatly in fashion at the time. More than 100 years later, the Florentine photographer, Vittorio Alinari, reports sea silk manufacturing in Sardinia. He speaks about a beautiful textile, used also for waistcoats: *"…una stoffa di un bel colore metallico, che si avvicina al rame, con la quale si confezionano delle sottovesti che, guernite di bottoni in filigrana d'oro, pure lavorati nel paese e nel Cagliaritano, producono bellissimo effetto…"* (Alinari 1915, 114). A waistcoat therefore seems a likely source for this piece.

Almost half of all items documented in inventories as sea silk are knitted (mostly plain, sometimes patterned). There are also crocheted objects, fabrics with woven or embroidered sea silk ornament and fur-like objects with a pile made of cleansed fibre beards. Besides the two woven textile samples presented here, only one woven scarf has been recorded. There are many questions to be answered about the origin and use of these pieces and much research remains to be done. Any future studies, however, should incorporate the identification of fibres by microscopy, as described in this paper.

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