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Textile technology in Nepal in the 5th-7th centuries CE: the case of Samdzong

Margarita Gleba^{1*} , Ina Vanden Berghe², and Mark Aldenderfer³ 

¹McDonald Institute for Archaeological Research, University of Cambridge, Downing Street, Cambridge CB2 3ER, UK

²Royal Institute for Cultural Heritage (KIK/IRPA), Jubelpark 1, B-1000 Brussels, Belgium

³School of Social Sciences, Humanities, and Arts, 5200 N. Lake Road, University of California Merced, USA

Abstract The first results of textile and dye analyses of cloth remains recovered in Samdzong, Upper Mustang, Nepal, are presented. The site consists of ten shaft tombs, dated between the 400-650 CE, cut into a high cliff face at an elevation of 4000 m asl. The dry climate and high altitude favoured the exceptional preservation of organic materials. One of the objects recovered from the elite Samdzong 5 tomb complex is composed of wool fabrics to which copper, glass and cloth beads are attached and probably constitutes the remains of a complex decorative headwear, which may have been attached to a gold/silver mask. SEM was used to identify the fibre sources of the textiles, which are all of animal nature. Two of the textiles are made of degummed silk. There is no evidence for local silk production suggesting that Samdzong was inserted into the long-distance trade network of the Silk Road. HPLC-DAD analysis permitted identification of a variety of organic dyes, including Indian lac, munjeet, turmeric and knotweed/indigo, while cinnabar was identified through micro Raman spectrometry. The results indicate that locally produced materials were used in combination with those likely imported from afar, including China and India.

Statement of significance Textiles are not commonly found in most archaeological contexts, yet when preserved in organic state they can be analysed using modern scientific techniques such as Scanning Electron Microscopy and High Performance Liquid Chromatography to uncover information about their fibre and dye sources. This information can be used to reconstruct the economic and social aspects of textile production and exchange in the past. Identification of silk fibres and munjeet and Indian lac dyes in the textile finds from Samdzong, Nepal suggests that imported materials were used in combination with those locally produced.

Data availability The authors confirm that all data underlying the findings are fully available without restriction. All relevant data are contained within the paper.

Keywords Textiles; dyes; SEM; HPLC-DAD; Nepal; silk

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1. Introduction

1.1. Archaeological textiles and their preservation

Textiles are, like any organic material, subject to rapid decomposition in archaeological contexts and their preservation requires special environments to prohibit their destruction by micro-organisms. Aridity, high concentration of salt, waterlogging, freezing, charring and mineralization are among the most common conditions that lead to preservation of textiles. Mineralised textiles are formed when metal corrosion products create casts around fibres retaining their external morphology and size almost unaltered (Chen et al., 1998). In Samdzong, textiles survived thanks to high elevation and relatively constant environmental conditions inside the caves, or due to mineralization in contact

with metal objects. Given the fact that such finds are exceedingly rare in Nepal, their systematic scientific analysis is of exceptional importance for our understanding of the local textile materials and techniques, as well as the mechanisms through which various communities developed and adapted new textile technologies to fit local cultural and economical needs.

1.2. Archaeological Context

Samdzong 5 is one of ten shaft tombs that define the Samdzong Mortuary Tradition, which is dated between 400-650 CE (Aldenderfer in press; Aldenderfer and Eng, 2016). The Samdzong tomb complex is found at an elevation of 4000 m above mean sea level in Upper Mustang, Nepal, on the east side of the Samdzong Khola, a small stream that eventually drains into the Kali Gandaki River (Fig. 1). The tombs of the complex,

*Corresponding author: mg704@cam.ac.uk

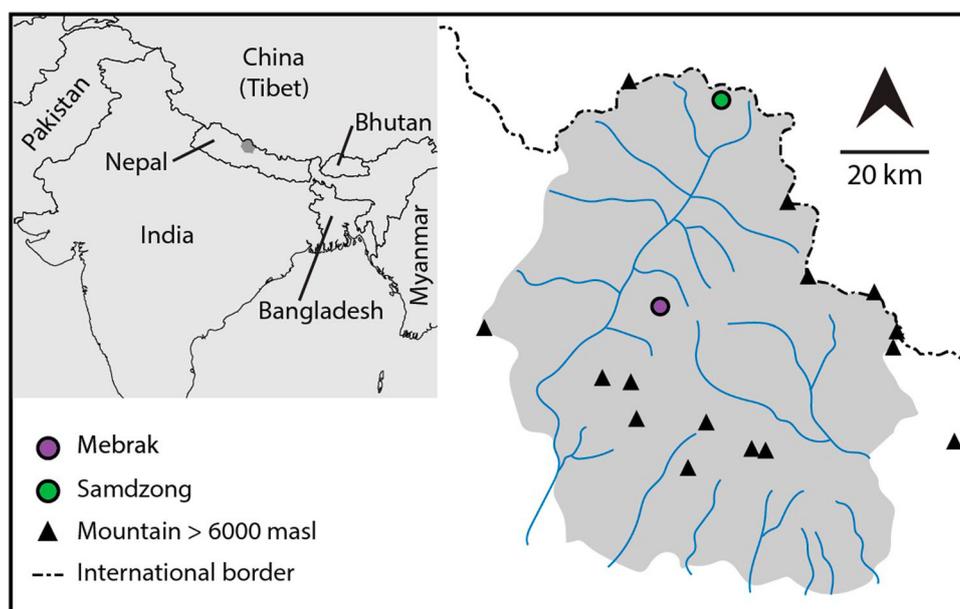


Figure 1 Map indicating the location of the site (Image: ©Mark Aldenderfer).

which are approximately 30 m above the modern ground surface and can only be entered through technical climbing, were excavated in prehistory into the soft conglomerate rock of a massive cliff face and were only exposed to view in 2009 following a seismic event that calved off the façade of the cliff, thus exposing the chambers. Unfortunately, this event led to the collapse of the ceilings of the chambers, which significantly disturbed the context of the finds. Although the soil matrix within the chambers is predominantly dry, water seepage into them over time corroded the iron objects within them, and led to the deterioration of other artifacts, including the textiles.

Although a total of 105 different individuals have been recovered from the tombs of the complex (Aldenderfer and Eng, 2016), Samdzong 5 contained only two sets of human remains: an adult of indeterminate sex, and a juvenile aged 8-12. The adult remains, disarticulated as an aspect of the post-mortem treatment of the dead in this tradition, were found in a large wooden coffin painted with a horseman motif (Aldenderfer 2013: Figure 5). Associated with the coffin were two large copper vessels and a ladle, iron daggers, wooden and bamboo cups and trays, copper and bronze bangles, and a wide variety of glass beads which number in the thousands. The most spectacular find was a gold/silver mask that we believe covered the face of the adult in the coffin (Fig. 2; Aldenderfer 2013: Figure 4). The mask has small pinholes around its edges, suggesting it had been sewn to a fabric. Most of the fabric remains described in this report were found in close association with the coffin and its contents. Samdzong 5 was constructed around 500 CE.

Chemical and technological analyses of the metals (Massa 2013) and glass beads (Dusseubieux 2015)

indicate that these objects were fabricated elsewhere; some of the metals appear to have been made either on the Tibetan plateau or in the Indian subcontinent, while the beads have multiple origins, including South Asia (possibly the Deccan or Sri Lanka), Central Asia, and Sassania. Together with the coffin and mask, these lines of evidence suggest Samdzong 5 is the tomb of a local elite. Comparisons with the other tombs, which generally have very limited range of cultural materials present, support this inference.

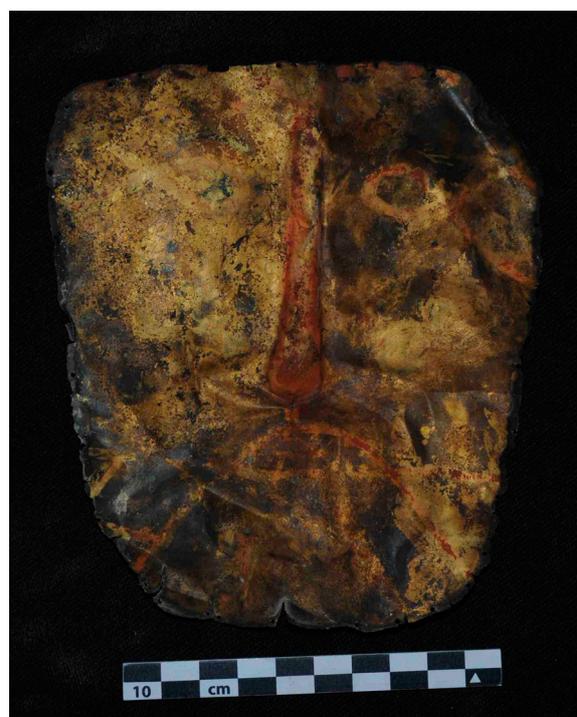


Figure 2 A gold/silver mask, possibly related to the textile finds (Image: ©Mark Aldenderfer).



Figure 3 Close-up of the dark tabby band from Sample 46 (Image: ©Margarita Gleba).



Figure 5 Horizontal braid between the textile and the copper alloy tubes from Sample 46 (Image: ©Margarita Gleba).

2. Material and methods

Organically preserved archaeological textiles can be investigated using a wide variety of analytical techniques, which result in important discoveries regarding their materials, date and provenance, thereby providing data about their function, movement, meaning and role in ancient societies. Organically preserved Samdzong textile remains were subject to technological analysis and fibre identification using low and high magnification, and material identification using transmission light microscopy (TLM) and scanning electron microscopy (SEM) for fibre analysis, high pressure liquid chromatography with diode array detection (HPLC-DAD) for organic dye analysis and micro-Raman spectrometry (MRS) for pigment identification.

2.1. Material

Samples measuring 0.2-1.5 cm in length were taken from each textile for SEM and HPLC-DAD analysis. Great care was taken to remove the smallest sample possible if no loose threads were available. Fine tipped stainless steel tweezers were used to separate



Figure 4 Close-up of the twill weave from Sample 46 (Image: Margarita Gleba).

the samples, which were placed in 1.5 ml low tension microcentrifuge tubes.

2.2. Methods

2.2.1. Analytical procedures: technological analysis

Textile characteristics recorded during analysis included textile weave, thread count, thread diameter and twist direction, as well as any other visible features. This was done using visual observation using hand-held lens with low power magnification and portable Dino-Lite digital microscope at different magnifications (20x, 50x, 230x).

2.2.2. Analytical procedures: fibre identification

Pre-industrial textile fibres can be of plant, animal or mineral origin. Fibre identification relies on the observation of the surface morphology and, where possible, cross section of a fibre using higher magnifications in TLM and SEM. In archaeological samples, the success of fibre material identification to species level is highly dependent on their preservation. Observation and diameter measurements of Samdzong samples were carried out using Hitachi S 3200N Scanning Electron Microscope at the Institute of Archaeology, University College London. The following instrumental settings were used: 15.00-20.00 kV accelerating voltage and working distance of about 10 mm in the back scatter electron detector (BSE), without any coating. The diameter of fibres was measured using SEM utility tool.

2.2.3. Analytical procedure: dye identification

Organic colorants can be of plant or animal origin. Identification of the dye source(s) is based on the separation of coloring compound mixtures extracted from the dyed fibers using high pressure liquid chromatography with diode array detection. Absorbance spectra together with retention times are used to

define each coloring compound by comparison with spectra from a user-generated reference spectra database developed of commercially and non-commercially available synthesized pure compounds, as well as of dye compounds extracted from plants and animals directly or obtained after extraction from dyed textiles. All references are taken under the same chromatographic conditions. The obtained compound composition provides information for the attribution of the biological dye source(s).

Each analysis of archaeological textile required a thread sample of about 5 mm length. Contaminating macroscopic substances were removed prior to analysis. Sample preparation was done by treatment in 250 μ L of a solution of water / methanol / 37% hydrochloric acid (1/1/2, v/v/v) for 10 minutes at 105°C after which the solution was cooled down rapidly under tap water. 500 μ L Ethyl acetate was added and after decanting of the upper phase, this ethyl acetate solution was dried in a vacuum evaporator. The dry residue was taken up in 30/30 μ L methanol/water from which 20 μ L was injected in the chromatography system (extraction 1) (Vanden Berghe et al. 2009). For the other extraction, the samples were treated with 200 μ L of a methanol / acetone / water / 2.1 M oxalic acid solution (30:30:40:1, v/v/v/v) for 30 minutes at 60°C, followed by centrifuging and vacuum evaporation. The residue was re-dissolved in 30/30 μ L methanol/water from which 20 μ L was injected in the chromatographic system (extraction 2).

The reverse phase chromatography system applied consisted of an Alliance HPLC instrument with automatic injection (Waters Chromatography BV). The mobile phase is composed of (A) pure methanol (grade: for HPLC > 99.8%), (B) a mixture of methanol and Milliq. water in the volumetric ratio of 1/9 and (C) a 5% phosphoric acid solution (85 wt% pro analysi), run according to the following gradient: 0-3 minutes: isocratic 23A/67B/10C, 3-29 minutes: linear gradient to 90A/0B/10C, 30-35 minutes: isocratic 23A/67B/10C. The elution program has a constant flow rate of 1.2 ml / minute creating a system back-pressure of 1600 psi. For the stationary phase a temperature controlled end capped LiChrosorb RP-18 column was used. The PDA detector (model 996) uses 512 diodes, scanning the absorbance within the wavelength range between 200 and 800 nm, with a resolution of 1.2 nm with 1 scan / second. The applied software system for data treatment was Empower 2. All equipment was from Waters Chromatography BV.

2.2.4. Analytical procedure: pigment analysis

The identification of the molecular composition of inorganic colorants on textiles was investigated using micro-Raman spectrometry (Invia, Renishaw, UK) with 785 nm laser excitation wavelength. This non-destructive technique was applied on a small fiber sample prior to the organic dye analysis.

3. Results and discussion

3.1. Textile characteristics

Three objects, each consisting of multiple elements were analyzed. The results are summarized in Table 1 and detailed description below.

Sample 46

Sample 46 included two larger textile fragments and several very small fragments of dark brown fabric, in relatively good condition but stiff and crumpled (Fig. 3). The fragments appear to be remnants of a band at least 12-15 mm wide and over 10 cm long; one simple selvedge is preserved, along which there are two perforations – possible needle holes remaining from sewing the band to another fabric, as in Fabric 2. Sample 46 also included numerous fragments composed of elements in a variety of material, which originally likely constituted a single object.

a) Horizontal cloth band of dark brown color (which appears to be the same as Fabric 1) ca. 15 mm wide with one intact simple selvedge (Fig. 3). One end of the fabric is folded onto itself. At least 4 random running stitches are visible on the surface on top of the fold.

The stitches attach the tabby band to:

b) Another cloth of lighter brown color sewn to the back of the tabby band (Fig. 4). The fabric is a 1/2 (or 2/1) twill, which has a complex border with loops parallel to the selvedge of the tabby band and protruding from under it.

The loops of the twill appear to be attached or terminate in:

c) Horizontal braid of lighter brown color (Fig. 5), from which come vertical threads that pass through

d) 14 copper cylindrical tubes ca. 12 mm long and 4 mm in diameter, now oxidized bluish-green and fused together, arranged in a row parallel to each other; the threads passing through the tubes are held together by another

Table 1 Summary of technical characteristics of the Samdzong textiles.

Sample	Type of object	Binding	Thread count system 1/system 2 in threads per cm	Thread diameter system 1/system 2 in mm	Thread twist system 1/system 2
46-1	Woven textile	warp-faced tabby	30/20	0.3-0.4	S2z/z
46-2	Woven textile	1/2 (or 2/1) twill	20/24	0.3-0.4/0.2-0.4	S2z/2z
46-3	Cloth bead	-	-	-	-
47	Braided cords	Braided cords	-	0.255	S2z
50	Woven textile	tabby	50/45	0.117-0.135/0.068-0.0.127	i/i
S13	Woven textile	tabby	50/30	0.135-0.156/0.109-0.123	i/i



Figure 6 Cloth beads combining with bands of different fiber and colour from Sample 46 (Image: ©Margarita Gleba).

e) horizontal braid of light brown color, 9-10 threads from which go into
 f) 7-8 vertical columns of turquoise color spherical or cylindrical glass beads, each column consisting of 4 or 5 beads. The threads exit each column of beads and are held together by
 g) darker color horizontal braid, threads from which connect to
 h) a single cylindrical element, possible cloth bead, incomplete, consisting of a yarn core around which 4 bands of varied colour fibre are preserved. Four similar cylindrical elements with slightly tapering ends survive and appear to be some sort of decorative element, with 6 bands of varied color preserved (Fig. 6).
 Based on the location and combination of the various elements, a possible reconstruction is suggested in Fig. 7.

Sample 47

Sample 47 consisted of four groups of copper tubular beads (19 in total) with threads passing through them and some braiding preserved on both ends, which would have connected the beads to other elements as in Sample 46. In one area, a loop is preserved which is similar to the loops present on the twill fabric in Sample 46.

Sample 50

Sample 50 consisted of multiple layers of extremely fine and fragile tabby textile (Fig. 8). The yarn in both systems is very lustrous and untwisted, typical of Chinese silks. It appears to have been colored red although not throughout and there is no distinctive pattern to the red areas.

Sample S13

Sample S13 is a fine tabby textile (Fig 9). The yarn in both systems is very lustrous and untwisted, typical of Chinese silks.

Mineralised samples

Two iron fragments with traces of mineralized textiles have also been recovered and the two textile types

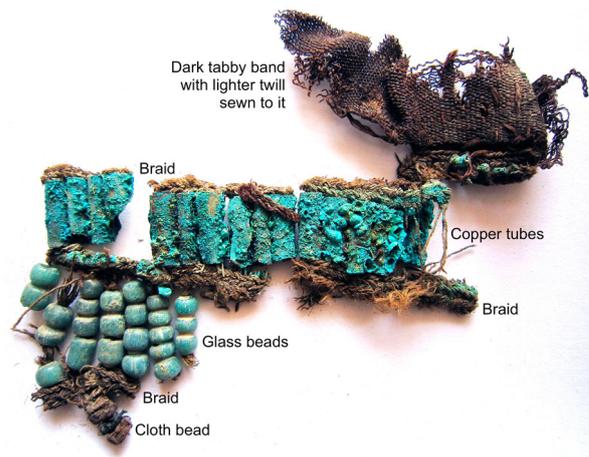


Figure 7 A reconstruction of the sequence of the various components of Samples 46 and 47 comprising the possible headdress (Image: ©Margarita Gleba).

observed appear to be similar to the tabby and twill fabrics in Sample 46. These have not been studied directly.

3.2. Fibre identification

Analysis carried out to date indicates that all fibres in the analysed samples are of animal nature. Definitive identifications were only possible for the silk samples.

Sample 46

Fiber surface is degraded in all samples analyzed, with scales on their surfaces largely gone, but their presence indicates that all fibers used in the various elements are of animal origin.



Figure 8 Fine open tabby of silk Sample 50 with irregular red colour (Image: ©Margarita Gleba).

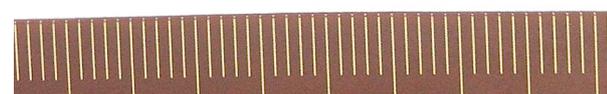


Figure 9 Fine open tabby of silk Sample S13 (Image: ©Margarita Gleba).

Fabric 1

Animal fibre (Fig. 10) of relatively fine and uniform quality, identified on the basis of faint traces of scales on the surface of fibers.

Fabric 2

The fibers from the braid between copper and glass beads is also of animal origin, with a wider fiber diameter range, including a fibre that exceeds 70 microns in diameter. The range is typical for sheep wool but scales are not sufficiently well preserved on the fiber surface for a definitive identification.

Fabric 3

The little cloth beads are made up of at least two, possibly 3 types of animal fiber. Coarse fiber band is made up by thick and long fibers of very large diameter with irregularly waved scale pattern, possibly horse mane (Fig. 11). The other bands are composed of much

Table 2 Fibre identification of the Samdzong samples.

Sample	Description	Fibre	Fibre diameter (microns)
46-1	Tabby	animal	10.3-17.2
46-2	Twill	animal	10.6-24.3
46-2	Light braid yarn	animal	11.8-34.3, 76.5
46-3	Dark blue band	animal	10.3-37.6
	Coarse fibre band	horse?	104-151
	Core	animal	13.6-25.2
50	Tabby	silk	6.07-10.1
S13	Tabby	silk	7.93-10.3

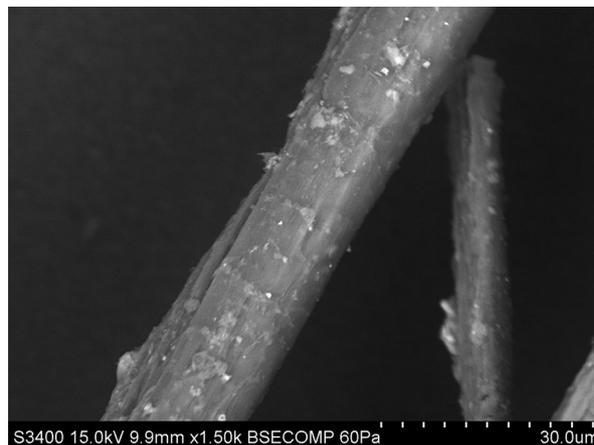


Figure 10 SEM micrograph of a fibre from Sample 46-1 showing remains of scales on the surface (Image: ©Margarita Gleba).

finer fibers but with more variation in diameter than in Fabric 1 (Fig. 12).

Sample 50

The SEM image of Sample 50 clearly shows that the yarn is not twisted (Fig. 13).

The raw material of Sample 50 is silk, likely of *Bombyx mori*, almost completely degummed, since fibroin filaments with triangular section are clearly visible (Fig. 14), although sometimes still adhering to each other in pairs. The individual fibers measure 6.07-10.1 microns in diameter, which also corresponds to the average diameter of degummed silk fibers (5-10 microns).

Sample S13

The raw material of Sample S13 is also silk, likely of *Bombyx mori*, almost completely degummed, since fibroin filaments with triangular section are clearly visible, although sometimes still adhering to each other in pairs. The individual fibers measure 7.88-10.3 microns in diameter, which also corresponds to the average diameter of degummed silk fibers.

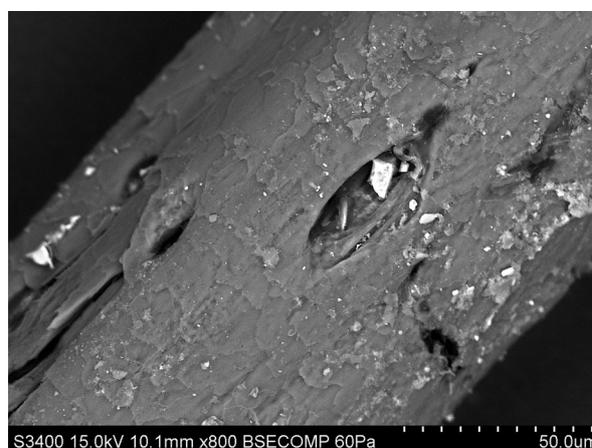


Figure 11 SEM micrograph of a large fibre with irregularly waved scale pattern and pits visible on the surface, possibly horse hair (Image: Margarita Gleba).

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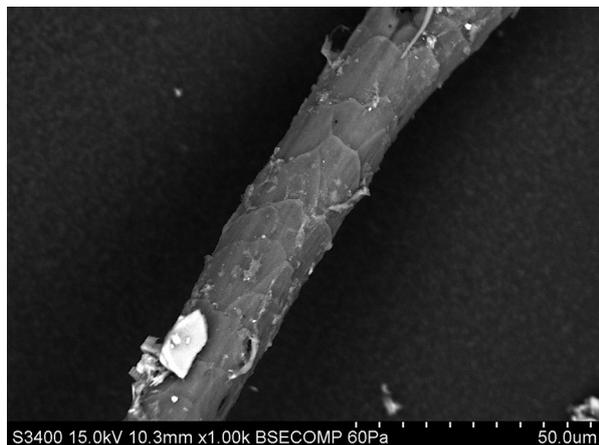


Figure 12 SEM micrograph of a fine fibre from the dark blue band of the cloth bead with clearly visible scales on the surface (Image: ©Margarita Gleba).

3.3. Dye analysis

The dye composition determined after HPLC analyses are summarized in Table 3. Each result is expressed as the relative ratio of the peak areas of the identified dye constituents given in percentages, after integration at a given wavelength (column 5). The extraction procedure applied for dye recovery is noted in the third column. The UV-Vis absorbance spectra of the detected dye precursor and compounds in the Samdzong samples are provided in Fig. 15.

Fabric 1 – sample 46-1

The sample of the dark brown warp faced tabby (fabric 1) consists of both warp and weft yarns. Dye analysis results in the detection of dye compounds from two different red biological dye sources.

The presence of laccaic acids A and E as well as erythrolaccin refer to the use of a red scale insect such as Common or Indian lac (*Kerria lacca* Kerr.) or Chinese lac (*Kerria chinensis* L.). (Zhang et al 2011). Thirteen species of the *Kerria* genus have been recorded in Asia. These species are native to India, Sri Lanka, Cambodia, Thailand, Vietnam and southern China and have been

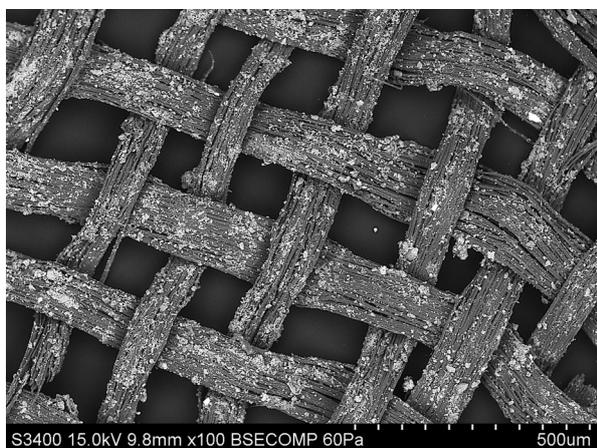


Figure 13 SEM micrograph of Samdzong Sample 50 with clearly untwisted threads typical for Chinese silk (Image: Margarita Gleba).

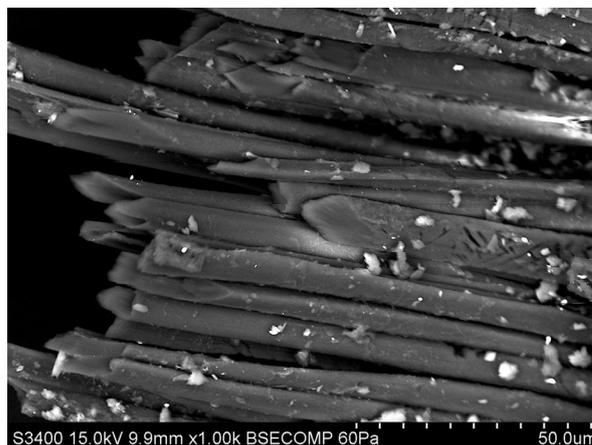


Figure 14 SEM micrograph of fibres, showing individual fibroin filaments, sometimes still adhering in pairs and triangular section of the fibres (Image: ©Margarita Gleba).

cultivated for thousands of years (Schweppe 1993, 272-276; Cardon 2007, 656-666). Most of the colorants can be obtained from the body of the insect, more precisely the eggs and the larvae, and produce a brilliant red color with good light fastness. Lac has little affinity to cotton and was primarily used to dye silk, wool and cashmere (Cardon 2007, 663).

Purpurin and rubiadin are two other components detected in fabric 1 and are anthraquinone dye compounds characteristic for red dyeing with the roots of a plant from the *Rubiaceae* family. The lack of the dye compound alizarin excludes madder (*Rubia tinctorum* L.) as a possible plant source. Most relevant oriental plant sources are Indian madder, also known as *munjeet* / *manjeet* (*Rubia cordifolia* L.), common in India, Sri Lanka and tropical Asia, or Naga madder from Sikkim in the eastern Himalayas (*Rubia sikkimensis* Kurz) (Cardon 2007, 129-134). Textiles dyed with *R. cordifolia* contain mostly purpurin, munjistin and pseudopurpurin, but little or no alizarin or 6-hydroxyrubiadin (Mouri and Laursen 2012, 105-113). However, munjistin as well as pseudopurpurin might be transformed during drying of the roots into purpurin and xanthopurpurin (Bechtold 2009). This dye composition correlates very well with the one found in the extract of a *munjeet* dyed wool sample present in the book *Natural dyeing processes of India* (Mohanty et al. 1987, 164). This reference sample is originating from Darjeeling (West Bengal) and consists of primarily purpurin, rubiadin, xanthopurpurin and lucidin, with a small amount of alizarin (unpublished analysis Textile Lab KIK/IRPA).

It can be concluded that the dark brown fabric 1 was dyed red using the mixture of Indian lac and roots of *munjeet*. Separate analysis of warp and weft yarns of this fabric (Table 3) excludes the possibility that each yarn type was dyed individually with one of the red dye sources. The reason for mixing two red dye sources is probably to obtain a specific shade of red colour. In Kamarup in Assam, such

Table 3 HPLC-DAD results table: Dye composition and Biological dye source(s) (samples 'Wa/We' are composed of warp and/or weft threads; compounds probably present as result of contamination are indicated by **)

Sample code	Sample Description	Extraction	Dye composition	λ (nm)	Biological dye sources
46-1	Fabric 1 dark brown Wa/We	1	34 laccaic acid A, 43 laccaic acid E, 15 purpurin, 7 erythrosin, 1 rubiadin	255	Indian lac + munjeet
	darker plied warp	1	64 laccaic acidA, 33 laccaic acid E, 3 purpurin	255	"
	lighter single weft	1	58 laccaic acidA, 38 laccaic acid E, 4 purpurin	255	"
46-2A	Fabric 2-A	1	trace of purpurin	255	traces of Indian lac +
	light brown Wa/We	2	traces of laccaic acid A and purpurin	255	munjeet
46-2B	Fabric 2-B	1	no dyes detected	255	no dyes detected
	brown Wa/We	2			
46-3A	Fabric 3-A	1	79 isatin, 4 indigotin, 12 purpurin, 2 indirubin, 3 rubiadin	255	indigo/knotweed +
	dark blue		(87 isatin, 10 indigotin, 2 indirubin)	(288)	munjeet
46-3B	Fabric 3-B	1	10 isatin, 2 indigotin, 88 purpurin	255	indigo/knotweed +
	light brown	2	(74 isatin, 26 indigotin)	(288)	munjeet +
			8 laccaic acid A, 32 indigotin, 3 curcumin, 58 purpurin	255	turmeric (+ Indian lac)
			(9 laccaic acid A, 13 indigotin, 70 curcumin, 8 purpurin)	(420)	
50A	Fine silk tabby red area	1	benzoic acid derivatives	255	no dyes detected
50B	Fine silk tabby brown area	1	benzoic acid derivatives	255	no dyes detected
S13	Fine silk tabby brown	1	no dyes detected	255	no dyes detected
		2		255	

mixture of dyeing, first with munjeet and followed by a second dyeing in a bath in which Indian lac has been soaked for two days, is a traditional recipe for cotton dyeing resulting in a brilliant 'vermillion red' shade (Mohanty et al. 1987, 21). In the Assam and Manipur regions, two local traditional recipes for silk dyeing using both lac dye and munjeet are known, however without any particular specification of the red color (Mohanty et al. 1987, 59). A combination of these sources was also detected in textiles found in the cave system in Mebrak, Western Nepal dated between 400 BCE and 50 CE (Alt et al. 2003).

Fabric 2 – sample 46-2A

In the more pale twill fabric (Fabric 2) sewn onto fabric 1, very small amounts of both Indian lac and munjeet

were found as well, although it is very probable that this fabric was not dyed; rather the presence of the dyes is due to contamination through contact with Fabric 1.

Fabric 2 – sample 46-2B

No organic dyes were found in the braid between the glass beads.

Fabric 3 – samples 46-3A and 3B

The dark blue band of the cloth bead (sample 46-3A) contains compounds of isatin, a precursor of indigotin, indigotin itself and its isomer indirubin (Fig. 16). These are marker compounds for dyeing with either an indigo plant species from the *Indigofera* genus or with dyer's knotweed (*Polygonum* sp. L.) (Cardon 2007, 354-366, 379-386). Natural indigo is one of the

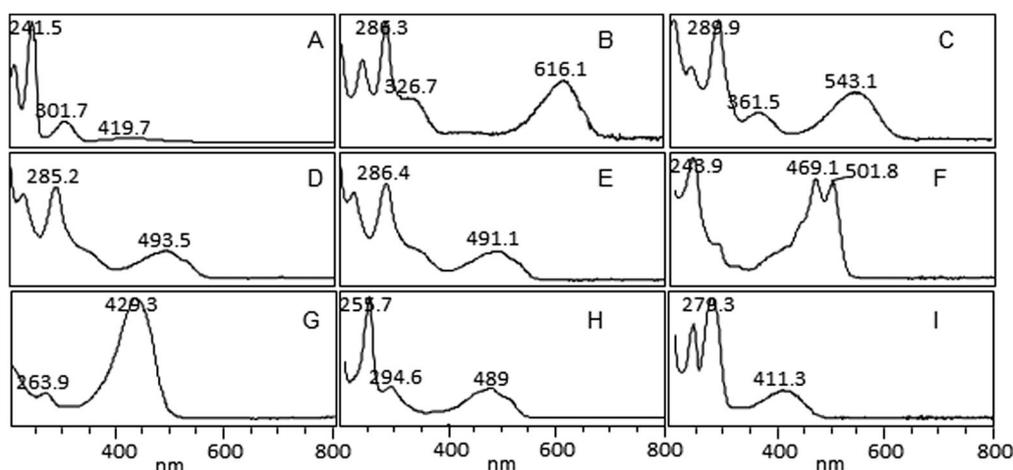


Figure 15 UV-Visible absorbance spectra of organic coloring constituents and precursors from the Samdzong samples: isatin (A), indigotin (B), indirubin (C), laccaic acids A (D) and E (E), erythrosin (F), curcumin (G), purpurin (H), rubiadin (I) (Image: ©Ina Vanden Berghe).

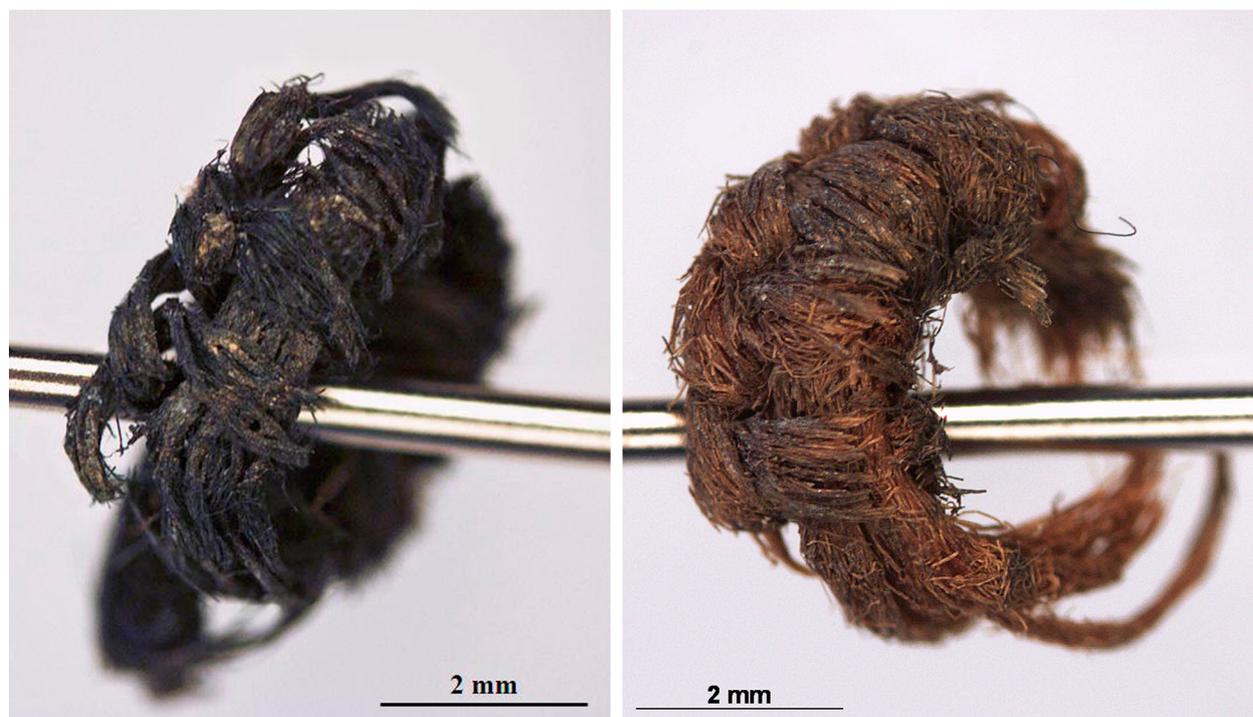


Figure 16 Dark blue (sample 46-3A) and reddish brown (sample 46-3B) bands of cloth bead (Image: ©Ina Vanden Berghe).

oldest organic dyes in the world. There are many different varieties of indigo plants native to Asia, although not all are used for dyeing. Dyer's knotweed is also a native plant in this region (Schweppe, 1993, 289-294). A combination of blue dyeing with indigo or dyer's knotweed and red dyeing with munjeet was used to create the dark blue band from a cloth bead. This mixture of dye components suggests an original purple or violet color of the band.

The reddish brown band (sample 46-3B) of the cloth bead is much more heterogeneous. While the external part of it contains some blue colour (indigo or knotweed dyed), possibly contamination from the adjoining blue dyed band, the inside is brown. Apart from purpurin, suggesting the use of munjeet, the compound curcumin was detected in this brown part, which is characteristic of the use of turmeric, also known as curcuma or Indian saffron. Curcumin is a yellow colorant deriving from the rhizomes of the small herbaceous plant *Curcuma longa* L. or other *Curcuma* species originating to south-east Asia (Schweppe, 1993, 180-181; Cardon 2007, 319-322). It is a substantive dye which gives a golden yellow color. In India, curcuma was sometimes applied as a preliminary dye prior to red lac dyeing, in order to obtain a scarlet red shade (Cardon, 2007, 321). Furthermore, also Indian lac is present in this sample, suggesting that red may have been the intended colour.

Sample 50A, 50B

HPLC-DAD analysis confirms the absence of organic dyes in the fine silk tabby. The red areas are the result of the local application or presence of the

inorganic red pigment cinnabar (HgS), detected by the micro-Raman analysis of the red-coloured sample 50A. On the brown areas of the fabric (sample 50B), no cinnabar was found. Presence of cinnabar may indicate that the textile was used as a substrate for painting, which corresponds well with textile analysis. The technology of dyeing with mineral pigments such as cinnabar was well developed in China already during the Shang (1600-1046 BCE) and Zhou (1046-256 BCE) Dynasties. Cinnabar was applied in different ways in ancient China. To paint patterns, it was spread directly onto the fabric, while it was also employed for dip-dyeing of silk threads before weaving. Fabrics coloured with cinnabar were precious, restricted for the upper-class, rich enough to afford such luxury (Wei Ji 1992).

Sample S13

No evidence for dyeing was found in the warp and weft thread composed sample from the fine silk tabby S13.

The mineral pigment cinnabar as well as the preserved organic dye sources munjeet, Indian lac, indigo or dyer's knotweed and curcuma, are all sources available in India or neighboring countries in East Asia.

4. Conclusions

Samples 46-47 likely constitute elements of a single object composed of several different textile elements as well as copper and glass beads, the sequence of which can be only partially reconstructed (Fig. 7). It is possible that it originally was a headwear of some

sort, which might have been attached to the gold/silver funerary mask found in the same tomb (Fig. 2). The article would have been quite colorful given the mix of metal beads, blue glass beads together with colored textiles and cloth beads. The principal warp-faced tabby must have been of brilliant red color due to a complex two-step dye procedure with the red from the lac insect and the roots of munjeet. The cloth beads were multicolored, with probably originally purple to violet bands obtained by dyeing with indigo or dyer's knotweed and munjeet, as well as orange or red bands dyed with a mixture of curcumin yellow, munjeet and some Indian lac was applied.

All of the detected fibres (possibly sheep wool and horse hair) and organic dye sources (munjeet, Indian lac, indigo or dyer's knotweed and curcuma) are native to India and the neighboring countries in East Asia, including Nepal.

Samples 50 and S13 are, on the other hand, very intriguing finds, since they are made of degummed silk, which was not produced in the area and is likely to be a long-distance import. Sericulture and the weaving of silk have been practiced in China since at least the late Neolithic period (Good 1995; Vainker 2004, 20; Peng Hao 2012, 68-73). The closest comparison to the Samdzong silks found so far is a tightly woven balanced tabby with untwisted warp and weft and 50/40 threads/cm used in one of the silk paintings from Dunhuang dated 7th-10th century CE, in the Stein Collection at the British Museum (Whitfield 2004, 291).

Cinnabar dyeing is also a technology developed in China. Cinnabar was mined in China already during the Bronze Age and by the Western Zhou dynasty (ca. 1046-771 BC) technology of refining and processing it was applied in textile dyeing. However, little of the dye was produced and it was restricted to luxury textiles of the elite.

Very few contemporary textile finds are known from Nepal. Mummies accompanied by textiles and other objects dated to 400 BC-AD 50 were found in caves at Mebrak in Muktinath Valley (Alt et al. 2003). Complete analysis of these textiles has not been published to date, but "finely woven textile samples are made of cotton, some of wool, a few of linen or other plant fibres" (Alt et al. 2003, 1531). According to the archaeobotanical evidence (seeds and seed capsules), cotton was cultivated in the Indus Valley since at least the third millennium BC and in the upper Ganges region from the second millennium BC (Fuller 2008, 9), but there is no evidence to date for its cultivation in Nepal. The cotton textiles found at Mebrak are likely to have been imported long distance. Samdzong textiles instead are made of silk and possibly sheep wool and horse hair. Some of the Mebrak textiles are made "from a mixture of materials - evidence of the elaborate techniques of textile processing the Mebrak population already possessed more than 2000 years ago" (Alt et al. 2003, 1531). While it is not mentioned how the various materials were used, the

combination of materials is also used in Samdzong Sample 46.

The Mebrak textiles were analysed for dyes using HPLC with on-line coupled UV/VIS-spectroscopy and "a wide range of organic dyestuffs could be identified: alizarin and purpurin (made from madder or related plants), indigo, lac-dye, ellagic acid (from tannin) as well as flavonol. Two other yellow and another red dyestuff remain to be identified by ongoing analyses. Remarkably enough, some of the dyes consist of complex mixtures of several, sometimes even similarly hued dyestuffs such as the combination of lac dye and madder" (Alt et al. 2003, 1531). Apart from the fact that munjeet was identified here instead of madder - though we can suppose that roots from different *Rubiaceae* species might have been applied according to their local availability - the reported dye mixture is similar to what is found in fabric 1 from the Samdzong finds. Unfortunately, due to the general description of the other dyes in the Mebrak textiles, further comparison of yellow and red dye sources is not possible.

The finds at Mebrak suggest contact with the neighboring regions, particularly with the Indian sub-continent. The discovery of silk at Samdzong also points to connections with north-east Asia and possibly indicates that the site was connected with the Silk Road.

Contemporary silks are known from sites well to the north of the region, in Qinghai on the NE fringe of the Tibetan plateau. Many of the major Central Asian sites on the Silk Road produced silks (Astana, Kashgar, Khotan, Turfan), as well as imported them from China (Sheng 2006). Recently a large number of silk textiles from the Munchaktepa cemetery near Pap in Uzbekistan dated to the 5th-8th centuries CE have been published (Matbabaev and Zhao 2010). On the basis of this material, Matbabaev and Zhao (2010, 227) suggest that silk production in the Fergana Valley developed already at the beginning of the Common Era under the influence of China. Looking at the wider region of Central-East Asia, most textile scholarship has focused of the more spectacular patterned silk finds (e.g. Schorta 2006 with extensive bibliographies), while little is known about the more mundane and simpler textiles.

What seems clear from the analysis of these textiles is a mixture of local and regional strategies for the acquisition of materials, including textiles. Locally produced materials were used in combination with those likely imported from afar. The presence of glass beads from south-east Asia or south India, as well as from Sassania, testify to the place Upper Mustang held in regional exchange networks, and the textile evidence provides deeper insights into other connections. Together, these data reinforce the notion that instead of being isolated and remote, Upper Mustang was once a small, but important node of a much larger network of people and places.

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Notes on contributors

Margarita Gleba received her Ph.D. in Classical and Near Eastern Archaeology from Bryn Mawr College (USA) and is currently European Research Council Principal Research Associate at the McDonald Institute for Archaeological Research, University of Cambridge. She has worked on excavations in Italy, Turkey and Ukraine. Her special area of study is the archaeology of textile production, including investigation of textiles, textile fibres, textile tools, as well as relevant written, iconographic and other sources.

Ina Vanden Berghe is educated in Industrial Sciences and is a scientist in the Research Department, Section Materials & Techniques at the Royal Institute for Cultural Heritage in Brussels since 1998. Her specialisation is the material technical study of organic material in historical and archaeological textiles and manuscripts.

Mark Aldenderfer is Dean and Professor at the University of California at Merced, and holds his degrees from Pennsylvania State University (Ph.D.) and Wake Forest University. His areas of specialization include the Tibetan plateau and the Himalayan arc, the archaeology of foraging societies, Archaic/Pre-ceramic Andes, comparative analysis of high altitude cultural and biological adaptations, the archaeology of Buddhism, and the archaeology of religion. He has conducted fieldwork in Tibet, Nepal, Peru, Argentina, Ethiopia, and at sites throughout the United States.

ORCID

Margarita Gleba  <http://orcid.org/0000-0001-7729-7795>

Mark Aldenderfer  <http://orcid.org/0000-0002-7033-4319>

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