

SOPHIA VAKIRTZI

Independent researcher  
sophiavakirtzi@hotmail.com

FRAGOULA GEORMA

Greek Ministry of Culture and Sports, Ephorate of Antiquities of Corfu  
fgeorma@culture.gr

ARTEMIS KARNAVA

Berlin-Brandenburgische Akademie der Wissenschaften, Inscriptiones Graecae  
karnava@bbaw.de

## BEYOND TEXTILES: ALTERNATIVE USES OF TWISTED FIBRES AND EVIDENCE FROM AKROTIRI, THERA

### ABSTRACT

Fibre crafts are among the oldest technological practices of mankind. Although commonly associated with textile manufacture, twisted fibres in the form of threads have always had a wider range of use in everyday life. Strings and ropes constitute a humble but essential category of fibre products deriving from the same technology and organic matter as threads. Due to their organic nature, however, they are rarely preserved in the archaeological record, unless special environmental conditions occur. This paper explores the research potential of the imprints of threads and strings in a study focusing on the alternative uses of fibre-spun

artefacts. The focus is on the Bronze Age Aegean imprints of threads and strings preserved on objects made of clay and on wall paintings recovered at Akrotiri on Thera. The technical properties of the original threads and strings are evaluated through observation of their imprints, and the fibre technology used for their production is assessed. The methodologies of spindle whorl metrology and experimental spinning are also integrated in the discussion. Ultimately, the use of threads and strings for a variety of purposes, including but not limited to textile production, is discussed.

### STRESZCZENIE

#### NIE TYLKO TKANINY –

#### ALTERNATYWNE ZASTOSOWANIA SKRĘCONYCH WŁÓKIEN I POZOSTAŁOŚCI Z AKROTIRI, THERA

Rzemiosło włókiennicze należy do najstarszych technologii znanych ludzkości. Skręcone nitki, chociaż zwykle kojarzone z tkaninami, miały znacznie szersze zastosowanie w życiu codziennym. Wyroby powroźnicze, takie jak sznury i liny, stanowiły bardzo istotną kategorię produktów, którą łączyły z produkcją tkanin technologia i surowce. Jednakże ze względu na organiczne pochodzenie surowców, wyroby tej kategorii bardzo rzadko zachowują się w materiale archeologicznym, o ile nie znalazły się w szczególnych warunkach środowiskowych. Artykuł analizuje potencjał badawczy odcisków nitek

i sznurków w odniesieniu do różnych zastosowań wyrobów powroźniczych. Badany materiał pochodzi z odcisków w glinie i tynku malowideł ściennych ze stanowiska Akrotiri na Therze, datowanego na epokę brązu. Parametry techniczne i technika produkcji odcisniętych wyrobów zestawione są następnie z danymi metrologicznymi przęślików z tego stanowiska oraz rezultatami badań eksperymentalnych. W artykule analizowane jest szerokie spektrum zastosowania nitek i sznurków, również poza produkcją włókienniczą.

**Keywords:** thread, string, imprint, Akrotiri, wall paintings, clay sealings

### a) Introduction<sup>1</sup>

The production of yarn was a vital component of prehistoric textile industries and was comprised of a complex multi-stage operational sequence, which began with the procurement of plant or animal fibres and culminated in twisting them into threads (Barber 1991: 9–22, 41–42; Tzachili 1997: 81–118; Andersson Strand 2015: 39–60). The technique of twisting fibres is called spinning, and it aims at providing length and coherence to the individual fibre elements and strengthening the end product (Barber 1991: 52). Ethnographers have recorded traditional and primitive spinning techniques which may vary to a degree in different periods and cultures (Crowfoot 1931). These ethnographic studies have advanced the interpretation of archaeological data which provides indirect evidence, usually in the form of textile tools and iconography, for the operational sequence of prehistoric thread manufacture in the Old World (Barber 1991: 42–78). Thus, two basic categories of prehistoric spinning have been distinguished by analogy to the ethnographic record – twisting fibres by hand and twisting fibres with a spindle – of which further varieties may be recognised (Crowfoot 1931). An alternative technique of prehistoric thread manufacture was splicing strands of fibres instead of twisting them (Andersson Strand 2015: 45–46). Splicing is archaeologically detected only through the end product, and in the Eastern Mediterranean and Near Eastern prehistoric contexts it has so far been documented only in Egypt, through the discovery of textiles woven with spliced threads (Barber 1991: 44–51). On the other hand, the implementation of the spindle may leave clear traces in the archaeological record, even if cloth is not preserved, in the form of spindle whorls – small clay, stone, or bone weights adjusted on the spindle shaft to enhance its rotation and ensure making a strong homogeneous thread.

In recent years, functional studies on textile tools from prehistoric sites in the Aegean and in the wider Eastern Mediterranean have opened new avenues in the investigation of textile technologies (Andersson Strand, Nosch 2015). Building on earlier ethnographic and archaeological works, the Centre for Textile Research (CTR) at the University of Copenhagen has set to test

various hypotheses regarding the function of spindles and spindle whorls through experimental archaeology. Within this research framework, the correlation between spindle whorl size and an end product thickness was empirically confirmed, although further insights into the type of fibres spun cannot be gained by spindle whorl analysis alone (Andersson Strand 2015: 48). Furthermore, comparative functional studies of spindle whorls (e.g. Vakirtzi 2015) have made clear that spinning was employed not only for the production of textile threads but also for coarser types of products. Thus, archaeological assemblages of spindle whorls may attest not only to textile thread production but also to the manufacture of strings, cordage, and ropes.

Strings and ropes have been called “the unseen weapon that allowed the human race to conquer the earth” (Barber 1994: 45) and ironically remain ‘the unseen’ aspect of fibre crafts in the wake of the renewed interest in textile archaeology.<sup>2</sup> They were manufactured according to the same basic principle of twisting fibres, but in this case either coarser materials were used or primary spun strands were plied into thick cords. Strings and ropes are considered a significantly earlier invention than woven textiles. Elizabeth Barber coined the term “String Revolution” to denote a stage in the technoeconomic evolution when indirect evidence for the use of string and rope appears in the archaeological record of the Upper Palaeolithic, and she has argued that this invention was a catalyst for cultural acceleration (Barber 1994: 42–70). In extremely rare circumstances, strings and ropes have survived from that period (Adovasio *et al.* 1996) and provide a direct testimony of Palaeolithic fibre crafts. In that early pre-domestication age, these products, as well as mats, were presumably manufactured of wild plant fibres and tree bark (Barber 1994: 42–70; Rast-Eicher 2005: 117–118) and must have had a wide use, from simply “tying things up” (Barber 1994: 45) to manufacturing secondary objects, such as jewellery and tools. Similar uses may be postulated for the Neolithic and the Bronze Age as well, so that string and rope can be seen as one of the oldest and most persistent technological achievements of humanity. Thus, the manufacture and use of strings and ropes in prehistory is an important research topic in its own right but also in relation

<sup>1</sup> We would like to thank Assistant Professor A. Ulanowska and Associate Professor M. Siennicka, the organisers of the Session TH1–13 (*‘Tradition and Innovation in Textile Technology in Bronze Age Europe and the Mediterranean’*) of the 22<sup>nd</sup> Annual Meeting of the European Association of Archaeologists (Vilnius, Lithuania, 2<sup>nd</sup>–4<sup>th</sup> September 2016), for inviting us to participate in this important meeting of textile specialists. Our warmest thanks go to the director of the Akrotiri Excavations,

Professor Emeritus C.G. Doulas, for entrusting us with the study of material from the site and for his support throughout the years. We would also like to thank the anonymous reviewers for their valuable suggestions on this paper.

<sup>2</sup> Notable exceptions to this tendency are papers such as Hardy’s (2008) and Grömer and Kern’s (2010), which focus on the study of strings and cordage. The latter, in particular, presents experimental work on the analysis of string imprints.

to textile archaeology: textile thread production and string or rope production must have had some degree of overlap and interdependence, at least in terms of raw materials procurement, sharing of technological know-how, and labour organisation. Therefore, a holistic understanding of prehistoric textile production calls for the exploration of alternative uses of twisted fibres as well.

To address prehistoric fibre crafts beyond textiles, it is necessary to advance the systematic collection and study of archaeological data providing information on the processes involved and the end products. The difficulty of such an endeavour lies in the intrinsically limited preservability of ancient organic material, which survives only under exceptional climate and soil conditions. Whereas actual prehistoric threads, strings, ropes, and textiles are rare archaeological finds in general, their imprints comprise a relatively large body of evidence. Depending on their preservation status, imprints of threads, strings, or ropes may retain technical characteristics of the original artefact such as structure (single and multiple spin or ply), direction of spin or ply, angle of spin, twists per centimetre, as well as thickness. The features of these negatives may then be assessed to infer the technical properties of the original artefact, which are essential to obtain knowledge on prehistoric fibre crafts or to re-evaluate and refine general patterns. For example, there is a widespread and long-standing opinion that in prehistory European and Anatolian techniques of spinning resulted in z-spun threads, while Egyptian techniques resulted in s-spun threads.<sup>3</sup> Thus, the direction of primary spin is considered a cultural variable that has been related to distinct technological traditions involving a variety of spindles used in the respective cultural spheres (low-whorl spindle in the Eastern Mediterranean *versus* high-whorl spindle in Egypt), as well as to the gestures and body movements necessary to handle each type of spindle (Crowfoot 1931; Barber 1991: 65). However, it is difficult to corroborate generalisations on such issues, since actual prehistoric textiles and threads are scarce finds in Europe, Anatolia, and the Near East compared to the bulk of material preserved and excavated in Egypt.<sup>4</sup> The imprints of spun products may potentially enrich the datasets from all regions, so that systematic

comparisons can produce statistically reliable results. Therefore, as archaeological research on textiles and fibre crafts advances, imprints of textiles, threads, strings, and ropes emerge as an important category of evidence to consider in theoretical discussions and integrate in research methodologies.

This paper addresses the use of twisted fibres beyond textile production. Thus, its aim is twofold. Firstly, to present examples of alternative uses of fibre craft products; secondly, to explore the research potential of a specific category of archaeological evidence of prehistoric fibre crafts, namely string imprints from the Aegean region in the Eastern Mediterranean. The focus is on the Bronze Age and in particular the first half of the 2<sup>nd</sup> millennium BC, as the investigated material was found in the Late Cycladic town of Akrotiri on the island of Thera. Fibre crafts at Akrotiri have been studied so far in relation to textile production (Tzachili 1990; 1997; 2007a; Vakirtzi 2015; forthcoming a). Textile production and consumption have a prominent place in the wider scientific discussion regarding the cultural relations between Thera and Crete during this period. The main issues in question are when, how, and to what degree the local Theran technological textile traditions were replaced by their Cretan counterparts. It is thus not a coincidence that the string imprints chosen for presentation and comparison in this study have survived on two categories of artefacts: produced locally and imported from Crete.

## b) The archaeological context of the study

Excavations in the Late Cycladic harbour town of Akrotiri on Thera have provided rich and diverse archaeological evidence for the study of textile production and consumption at this site: artistic representations of cloth and garments on the exquisite wall paintings (Doumas 1992) and textile tools (Tzachili 2007a) are the most explicit testimonies of the aesthetic and technological choices of the inhabitants of Akrotiri with respect to their textile culture.<sup>5</sup> The Linear A tablets discovered in the town, including among the recorded items at least 200 cloth products (Boulotis 1998), testify to economic

<sup>3</sup> The letters s and z are used in the textile technical terminology to describe the clockwise and the counter-clockwise direction of spin respectively, which results in the configuration of a thread with a slant similar to the central part of these two letters (Barber 1991: 65–66; Andersson Strand 2015: 46; Gleba 2017: 1206). Furthermore, the convention adopted by the Centre for Textile Research is to denote primary spin with lowercase letters and secondary plying with capital S and Z (Skals *et al.* 2015).

<sup>4</sup> For an updated survey of ancient textile fragments, especially from Europe, *cf.* Gleba, Mannering 2012. This volume highlights recent studies of s-spun threads outside the sphere of Egyptian influence in a wide time-frame (“from prehistory to AD 400”). The z-spin direction, therefore, does not appear to have been an exclusive technique in European textiles. However, with regard to Egyptian prehistoric textiles, a re-evaluation of the s-spin direction as the dominant spinning technique has not yet been published in a recent synthesis.

transactions involving textiles. On a different level, bioarchaeological remains such as bones of ovicaprids and fibre plant seeds may be informative in regard to husbandry and agricultural practices which are often relevant to the economy of textile fibres. Thus, analyses of the archaeozoological remains found at Akrotiri indicate local wool production (Trantalidou 2001; 2008), while linseed identified among carbonised seeds supports the hypothesis of local flax cultivation (Sarpaki 1992). An extremely rare and lucky find, a moth cocoon found at the site, has triggered a scientific discussion on the possible use of wild silk as a textile fibre in the Bronze Age Aegean (Panagiotakopulu *et al.* 1997; Panagiotakopulu 2000). Last but not least, the recent discovery of textile fragments and threads positively demonstrated the use of linen and woollen cloth in Late Cycladic Akrotiri (Moulh  rat, Spantidaki 2008; Spantidaki, Moulh  rat 2012).

Synthesis of the data has allowed for a reconstruction of the local textile industry whose scale and intensity are exemplified by the large assemblage of loom weights found in the ‘West House’ (Tzachili 2007a). The level of specialisation is likewise indicated by the distribution of textile tools in just some of the excavated buildings (Tzachili 2007b). The skill of the weavers and the fineness of the fabrics woven at Akrotiri is suggested by the garments depicted on the wall paintings, such as the transparent bodice of the so-called ‘necklace-swing-er’, a female figure among the ‘Adorants’ which decorated the walls of the Lustral Basin in ‘Xeste 3’ (Dumas 1992: 128–129; 136–139). Textiles were woven *en masse* to meet the demand not only for elaborate garments, furnishings, and beddings but also for sails, a type of cloth which would have been indispensable for islanders as soon as the sailing ship was adopted in the Aegean at the turn of the 3<sup>rd</sup> to the 2<sup>nd</sup> millennium BC (Broodbank 2000). The upright warp-weighted loom equipped with discoid loom weights, a technology adapted from Crete (Tzachili 1990), was an effective solution for such textile production and was introduced in Thera at the beginning of the Middle Cycladic period (Vakirtzi forthcoming b).

The thread manufacturing technique, on the other hand, was a traditional technology used at Akrotiri at least since the beginning of the Early Bronze Age (Vakirtzi forthcoming a), and in the Cyclades, more generally, ever since the islands were permanently settled in the Late Neolithic (Evans, Renfrew 1968; Vakirtzi forthcoming c). This technology consisted of twisting fibres with a spindle equipped with a spindle whorl. The corpus of the spindle whorls collected from the excavations of Late

Cycladic Akrotiri has amounted to forty-one specimens so far. Six of them, originating from the excavation of the ‘West House’, have been published (Tzachili 2007a). The remaining were studied in the frame of a doctoral dissertation on prehistoric yarn production (Vakirtzi 2015). In the latter study, functional analysis has shown that a variety of spun products was manufactured in the town. Tools vary from extremely small and light (Vakirtzi 2012) to large and heavy.<sup>6</sup> The analogy between whorl size and thread thickness allows us to postulate general types of products from tools in comparative terms: a small and light whorl was suitable for the manufacture of a fine thread, while a considerably bigger and heavier specimen would have been used for thicker products (Andersson Strand 2015: 48), some of which may have been used beyond textile weaving. Strings and ropes have indeed been found at Akrotiri in a relatively good state of preservation. Some of them were studied in a preliminary manner by Yolie Spantidaki and Christophe Moulh  rat (Spantidaki, Moulh  rat 2006). The researchers reported five cases of strings made of plant fibres, most often of primary z-spun threads plied into S-ply strings. Plant fibres are confirmed as a basic raw material, while primary twist supports, in all of these cases, the z-direction technique.

### c) Materials and methods

Complementary evidence for fibre crafts can be sought in the form of imprints of spun products (threads or strings) preserved in the archaeological record at Akrotiri. This study discusses two main categories of archaeological finds from the Late Cycladic town revealing two distinct uses of spun products and originating from different localities. The first category includes a Thera cultural product, the wall paintings, where string has been used as a drafting device. The second category includes sealings made of unfired clay, for which string had been used as a binding medium. These sealings originate from Crete and were imported to Thera. Therefore, the comparison of the fibre-spun products in the form of their imprints is meaningful in view of the question of the technological traditions of the two islands and the cultural relations between them. This paper does not intend to offer an exhaustive presentation of all the imprints available. Instead, it offers a preliminary study providing some examples for further research and highlights the challenges emerging from this kind of approach to the archaeological investigation of the fibre crafts.

<sup>5</sup> On the term ‘textile culture’, cf. Gleba 2017: 1206.

<sup>6</sup> See below, part f.

With regard to the reconstruction of the technical properties of the impressed threads and strings, we have adapted our technical description from the methodology for yarn description developed by the CTR. Within the CTR's project '*Textiles, Tools and Contexts*', experimental spinning was undertaken with the aim to test the function of prehistoric spindle whorls. Spinning samples made of wool and flax were produced by using spindles equipped with replicas of prehistoric spindle whorls, and a protocol for the evaluation of the spinning samples was developed. This evaluation involved systematic observation and description of the yarn according to three main criteria: thread diameter, spinning angle, and thread fuzziness – the latter being a non-quantifiable variable. It was also decided that at least 20 points of observation and measurements should be determined along the length of a spinning sample. The main objective of the evaluation of the spinning samples was to estimate what the experimentally produced threads could reveal about prehistoric techniques (Möller-Wiering 2015).

A basic difference between describing spinning samples and describing archaeological threads or imprints lies in the fact that the latter may be biased by the state of preservation: it is often the case that very small fragments of threads survive or that imprints do not run at length on the artefact which preserves them. Another factor, which influences the evaluation of imprints, is the degree of direct accessibility of the researcher, often depending on the fragility of the artefact.

In this preliminary study all the imprints were examined macroscopically. The observations in the case of the wall paintings were made directly on the archaeological material, but the extremely fragile nature of the sealings did not allow for their repeated direct manipulation; therefore, high resolution photographs of the imprints and their casts were chosen instead. The number of points of observation and measurement were dependent in each case on the quality of a particular imprint. The objectives were to a) measure the width of the imprint which corresponds to the original thickness of the spun product, b) distinguish its structure, whether single-spun or plied, c) define the twist direction as preserved on the imprint or as recreated on the cast of the imprint, and d) measure the number of twists per cm, thus assessing how tightly or loosely spun the original product was.

#### **d) Wall painting imprints**

##### **Wall paintings**

In the Thera wall paintings production, preparation of the wall surface by a painter was followed by a tripartite separation of the surface dedicated to the drawing with the use of string imprints on the still humid plaster (Georma 2009: 84). The separation of the surface

was a basic rule and procedure in the Thera wall painting production, as it made managing the drawing easier for the painter: the upper part would be dedicated to floral and stripe decoration, the central part to the main configuration, while the lower part would provide a solid base for the representation.

The separation was executed by the use of a string, stretched from side to side between two vertical edges of the wall painting and subsequently pressed on the humid surface of the plaster. The exact moment of this procedure has not yet been verified, but certainly the degree of humidity of the plaster was important: if it was more humid than necessary, the imprint would vanish (Asimenos 1978: 575). Therefore, the string imprint was probably created on a surface nearly but not fully dry.

At Akrotiri on Thera the string imprint technique was very common and facilitated the drawing procedure. Conversely, in Egyptian wall painting production string imprints for the division of the plaster surface were not common, while red colour was instead used to prepare the drawing with the same result (Shaw 2003: 186).

On the material from 'Building Beta', the case study of the wall paintings for the present article, an extended use of string imprints was noted, especially on the frescoes from Room 1: the groups of the 'Antelopes' and the 'Boxing Boys' have a continuous tripartite division of their surface with a unified drawing on the upper and lower parts and a different representation in the central parts (Georma 2009: 86). The string imprints, in this case, were very helpful to ensure morphological homogeneity of the drawing, while technically the imprints, were very well-made and preserved well enough to enable observation.

On the other hand, in Room 6, due to adoption of a more free representation as the main configuration of the tripartite division, *i.e.* monkeys on a rocky landscape, the painter applied string imprints only on the upper part for the execution of a severe drawing with colourful stripes where the adoption of the string guidelines was inevitable.

The use of the string for the organisation of the drawing surface is attested more or less in the majority of the uncovered plaster material at Akrotiri: 'West House', 'Xeste 3', 'Xeste 4', 'House of the Ladies' (Doumas 1992), and was therefore considered by the Thera artists as a very useful instrument for painting preparation.

##### **Imprints**

To evaluate the technical properties of the strings used in the creation of these frescoes, we focused on selected areas where the imprints are well-preserved. It should be stressed that imprints are negatives, so that the twist direction of the original product was the exact opposite of the one observed on the imprint.

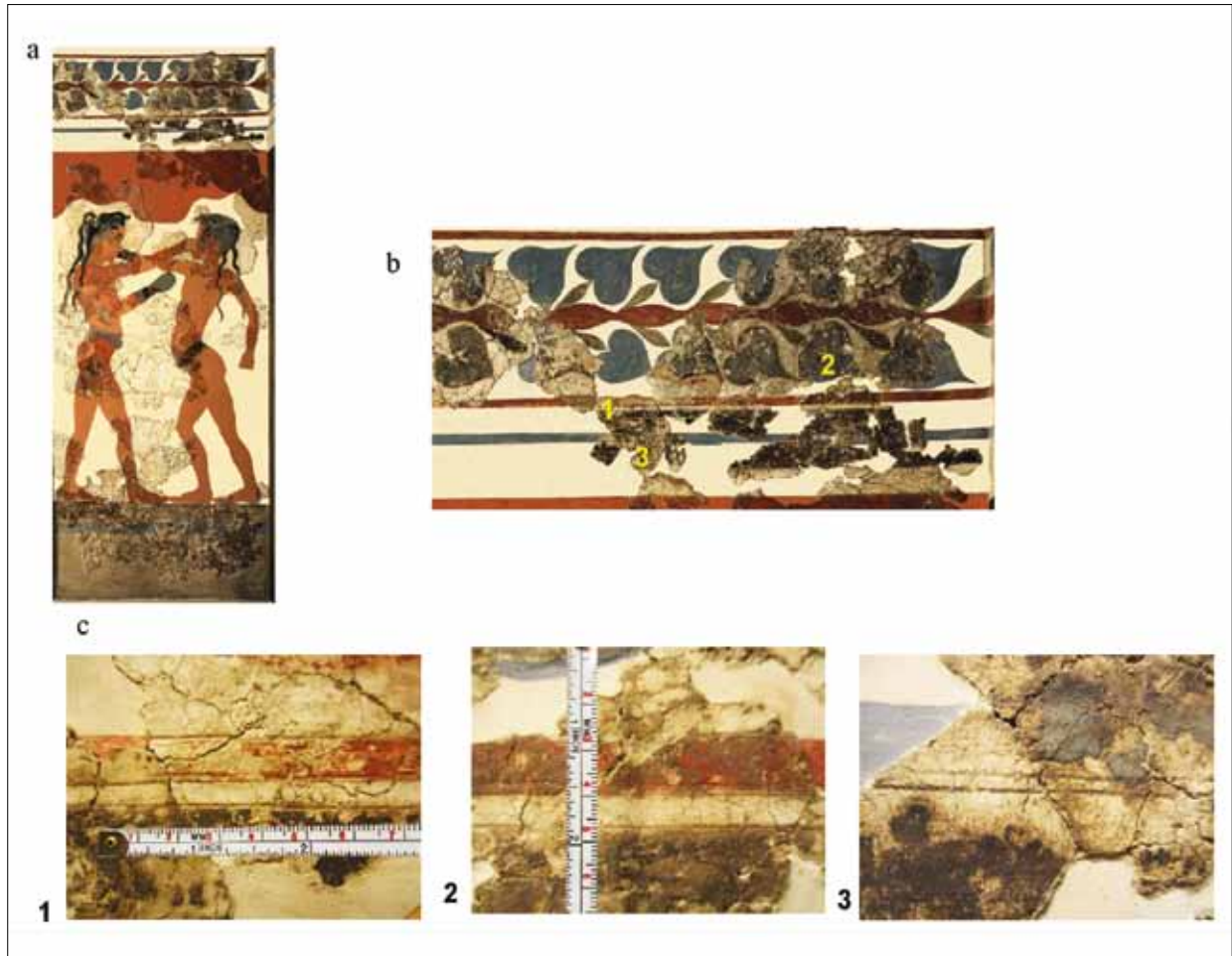


Fig. 1. a. 'Boxing Boys', 'Building Beta', Room 1, South Wall (height: 2.75 m, width: 0.94 m.; after Doulas 1992: Fig. 79); b. The foliate band with an indication of the points of observation of the imprints (1–3); c. Points 1–3 in a close-up (courtesy of the Akrotiri Excavation Archives).

In the case of the 'Boxing Boys', the imprints were measured at three points on the upper part of the composition, which is essentially a foliate band enclosed within thin coloured stripes: point 1 is on the upper limit of the dark stripe, point 2 on the lower limit of the red stripe, and point 3 just below the blue stripe (Fig. 1). At points 1 and 3, the width of the imprint was 1.5 mm, but at point 2 it was twice as much, *i.e.* 3 mm. In all three cases, the negative of the string had a z-twist direction, therefore the original was either s-spun or S-plied. However, it was not possible to discern macroscopically whether this is the primary twist or a plied string. Yet, the number of twists appeared homogeneous and rather consistent at all three points, as we measured 6 to 7 twists per cm.

In the composition of the 'Antelopes', three points on the upper part were observed and measured as well. They also belonged to the horizontal string imprints defining the drawing of thin colour stripes: point 1 is on the lower limit of the upper red stripe, point 2 is below the

lower red stripe, point 3 is a little to the right from point 2 (Fig. 2). At point 1, the width of the imprint was 2 mm. At points 2 and 3 it measured 1.5 mm. In all three cases, the negative of the string had a z-twist direction, so the original was either s-spun or S-plied. Again, it was not possible to conclude, if this was the primary spin or a plied string. In this composition as well, the string had 6 to 7 twists per cm.

As a general conclusion, it could be observed that the strings used by the painters were meticulously spun. The consistency of the number of twists per cm suggests that their manufacture was mechanised, that is, that they were produced with the implementation of a spindle equipped with a whorl. The thickness of the original products may have ranged from 1.5 to 3 mm. Two basic questions could not be answered through macroscopic observation: first, whether the z direction of the twist corresponds to primary spinning or not; and second, the nature of the fibres used.



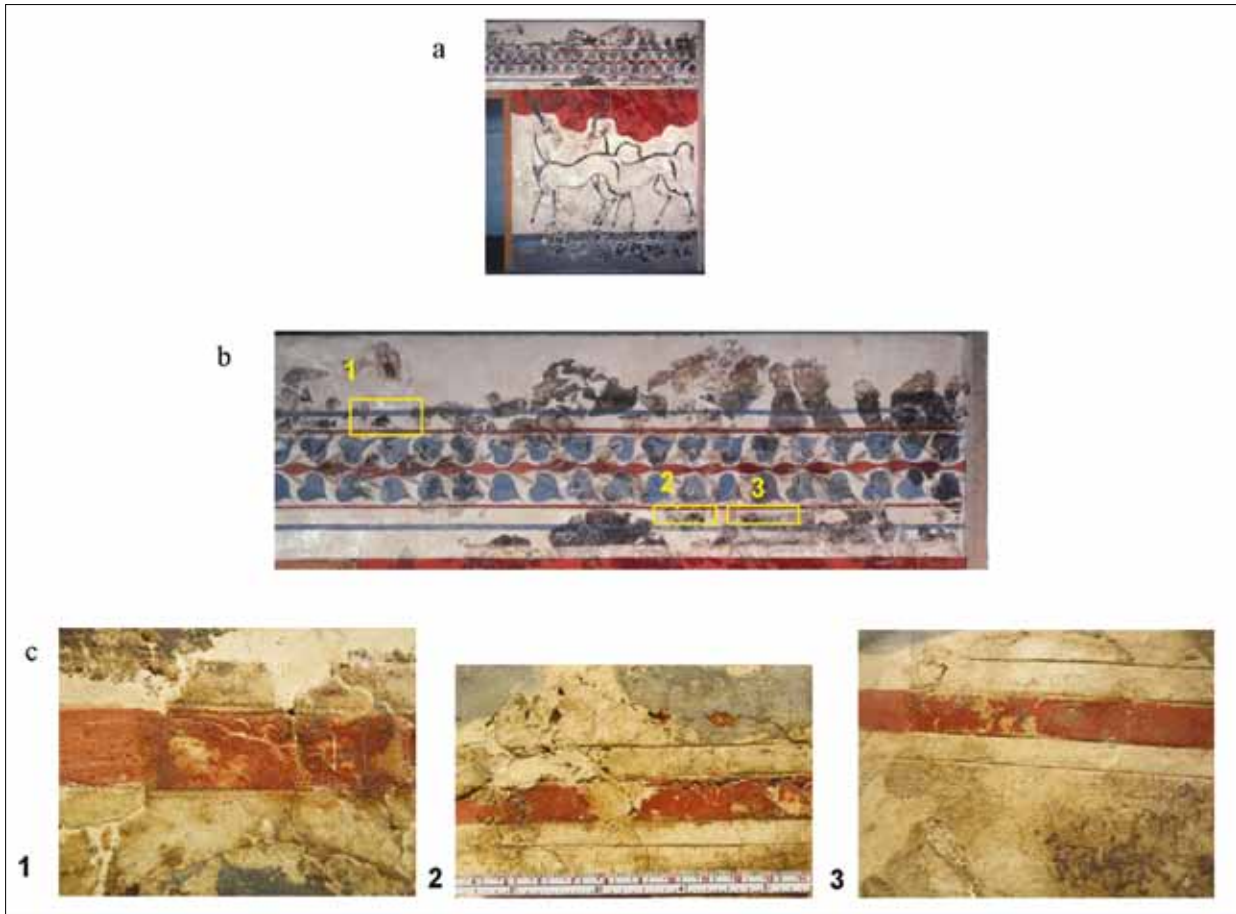


Fig. 2. a. 'Antelopes', 'Building Beta', Room 1, West Wall (height: 2.75 m, width: 2 m; after Doulmas 1992: Fig. 83); b. The foliate band with indication of the observed imprints; c. Points 1–3 in a close-up (courtesy of the Akrotiri Excavation Archives).

### e) Clay sealing imprints

#### The clay sealings

A unique testimony regarding strings at the site of Akrotiri on Thera is provided indirectly by string impressions on clay nodules. The testimony in question survives on the back of small-sized clay sealings recovered at the site of Akrotiri (Doulmas 2000). These particular sealings belong to a type known as 'flat-based' sealings (Fig. 3) because one of their sides, the one usually referred to as their back side, is relatively flat, since it was pressed against a (relatively) flat object when the clay was still moist (Hallager 1996: 135–158). On the basis of the characteristic imprint, the object they were pressed against was definitely made of leather (Pini 1983; Weingarten 1983). Although initially it was suggested that the leather had been wrapped around some small-sized packets (hence the term devised by Pini, *Päckchenplomben*), the surviving impressions demonstrate beyond doubt that the leather was only folded over multiple times (Fig. 4). These small folded pieces of

leather are assumed to have functioned much like parchment, serving some sort of administrative recording purposes and playing some yet unspecified role in exchange transactions (Karnava 2008). It also seems that the string was wrapped around the leather at the same time as layers of clay were stacked one after the other on top of the leather and also kept together by the wrapping string (Karnava 2018: 102–104). The string had been wrapped around the leather and the clay multiple times in order to keep them folded together, as well as to make sure that the clay would stay in place after it became dry. The last stage of the procedure was to stamp the clay with one, two, or even three different seals. It is believed that the stamped clay and the folded leather underneath were dispatched to localities outside their actual place of manufacture. What remains today, after the leather was obviously removed from the clay sealing or decomposed, is a small lump of dry, unfired clay bearing the impression of a leather piece wrapped in string on one side, and the impressions of one or more administrative seals on the other(s).

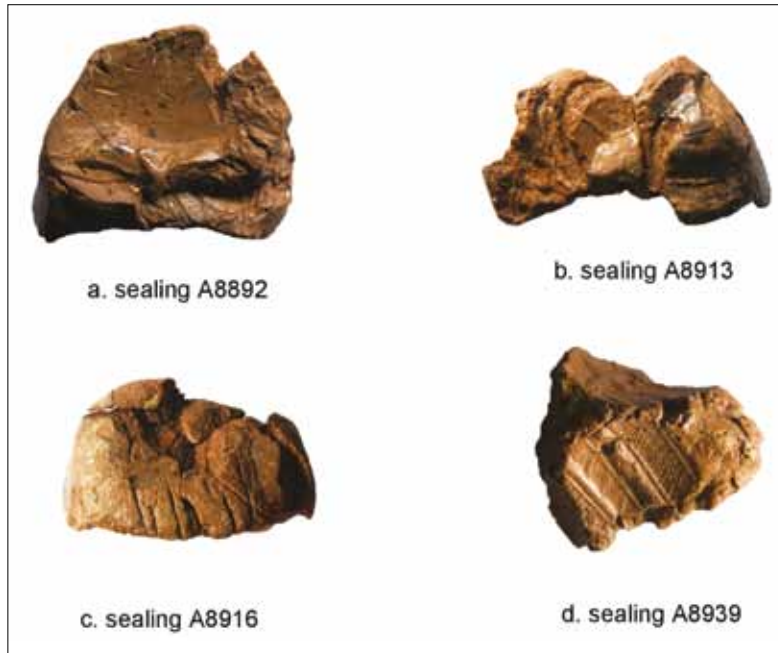


Fig. 3. a–d. Clay sealings nos A8892, A8913, A8916, and A8939 found at Akrotiri on Thera (courtesy of the Akrotiri Excavations Archives).

These sealings represent a specific stage in the history of the southern Aegean and most notably a specific stage in Minoan history. This sort of sealing has been found in a number of archaeological sites on the island of Crete, in deposits that date to the so-called Minoan Neopalatial period, roughly dating to between 1700 and 1450 BC. The evidence from Akrotiri does not represent local technology, that is to say that the clay sealings were imported to Akrotiri ready-made, *i.e.* it is certain that

they had been prepared in some locality (or localities) on Crete but were then sent off to Thera (Karnava 2008: 378). Therefore, the strings preserved as imprints on the sealing clay originated on Crete.

### The imprints

For this study, the string imprints were examined on high resolution photographs as well as on the casts

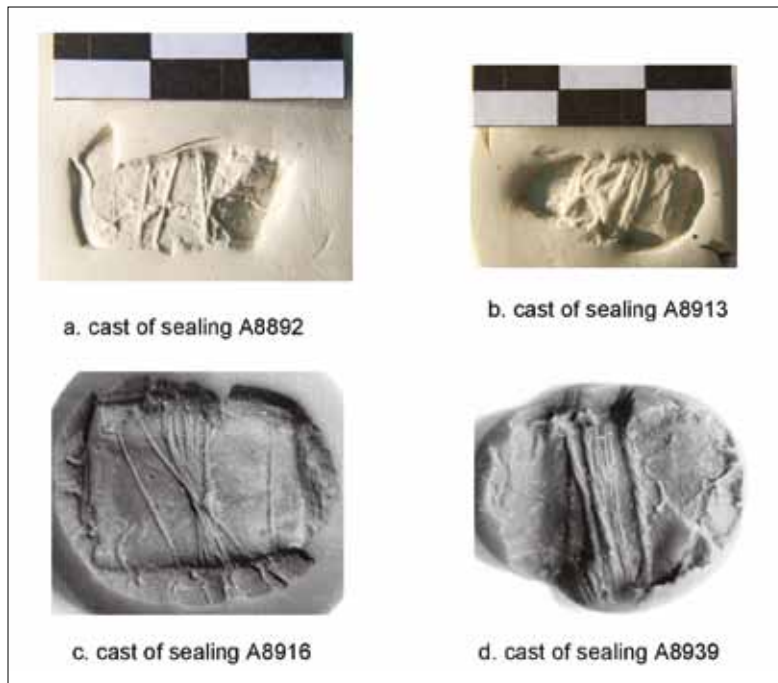


Fig. 4. a–d. Casts of the folded leather and thread imprints under clay sealings nos A8892, A8913, A8916, and A8939 found at Akrotiri on Thera (courtesy of the Akrotiri Excavations Archives).



of four sealings (Fig. 4). The cases discussed here represent a very small percentage of the total number of string imprints from the Akrotiri sealings. The imprints on clay were negatives as in the case of the Thera wall paintings, but their casts recreated the original twist direction.

In general, observation of the details was very challenging. It was easier to determine the direction of the spin or to measure the width of the imprint than to calculate the number of twists per cm. The casts of sealings nos A8892 and A8913 (Fig. 4.a–b) have imprints which are 0.4 to 0.5 mm and 0.6 mm wide, respectively. Extremely low relief, s direction slants were observed, which suggests that these strings were s-spun. It was not possible to observe on the casts if this was a primary or a secondary spin. The cast of another sealing, no. A8916 (Fig. 4.c), showed a clear contour of a folded piece of leather which was  $1.9 \times 1.3$  cm. A very thin thread was wrapped tightly around it. The width of its imprint is 0.3 mm. Again, a very low relief s sloping configuration suggests an s-twist direction. Lastly, sealing no. A8939 (Fig. 4.d) bears one of the best-preserved and widest string imprints. It is 1 mm wide with an s-twist direction and has 5 twists per cm.

Given the examples above, it can be suggested that the Cretan administrative authorities made use of very fine strings, best classified as threads,<sup>7</sup> in order to wrap the folded leather pieces tightly. Although it is impossible to confirm whether these s-spun threads were single or plied from even finer ones, in any case their manufacture required considerable skill and care, as well as tools with rather small and light spindle whorls, at least for the finest products. Just as in the case of the wall paintings, also for the clay sealings it was not possible to detect evidence leading to identification of the fibres used.

### f) Tools and products: correlating imprints and spindle whorls

The examination of thread and string imprints and the evaluation of the technical features of the original pro-

ducts provide a possibility to enrich our knowledge on fibre technology and to complement the data gained through textile tool analysis. It must be pointed out that this correlation is based on the assumption that the imprint's width corresponds to the original product's thickness.

It is highly probable that the strings whose imprints are preserved on the Thera wall paintings were produced at Akrotiri. In this case it is interesting to review the spindle whorl data from the site and to discuss which types of the tools found at Akrotiri could have been used to manufacture such strings. Late Cycladic deposits at Akrotiri yielded so far a total of 41 objects which were identified and studied as spindle whorls (Vakirtzi 2015). One of the analyses undertaken was a metrical classification of these tools according to their size class in order to infer the types of spun artefacts produced locally. This kind of analysis stems from the principle that the size of a spindle whorl, *i.e.* its weight and diameter, directly affects the thickness and the quality of the desired end product (Andersson Strand 2015: 47–48).

Metrical classification was applied to 30 out of the 41 whorls, *i.e.* those which were intact or almost intact and thus preserved all or almost all of their mass. They were classified according to their diameters and weights, which are considered the most important functional parameters, each affecting the speed of rotation of the spindle and the tension provided to the fibres accordingly (Barber 1991: 43–53). The results of the analysis demonstrated that a range of different fibre qualities were spun at Akrotiri into various types of products (Fig. 5). The manufacture of very fine and tight threads is indicated by six spindle whorls weighing between 2.9 and 10 g, with diameters between 1.6 and 2.5 cm. At the other end of the range are five spindle whorls weighing between 25 and 35 g, with diameters between 3.1 and 4.5 cm, which were used to make significantly coarser products. Between these extremes belongs the majority of Late Cycladic spindle whorls, with weight values between 10 and 25 g and diameters measuring between 2.5 and 5 cm. These twenty spindle whorls represent the main 'production line' of the Akrotiri Late Cycladic spinning

<sup>7</sup> According to one classification system, the criterion of distinction among different types of spun products is their diameter. Thus, following that classification and the related terminology, any spun product with a diameter of up to 2 mm is classified as a thread, those measuring between 2 and 8 mm in diameter would be called cords, while a product with a diameter of more than 8 mm would be called a rope (Andersson Strand 2015: 48, with further reference to Rast-Eicher 1997: 305–313). However, it must be born in mind that the classification so far has remained largely subjective and arbitrary in the archaeological textiles literature. Thus, it is suggested here that a robust classification

system of spun products necessitates a survey and comparison of a large body of data and employment of more than just metrical criteria to distinguish among their different categories. Here, the term 'string' is used to refer to spun products whose function was unrelated to textile production, *i.e.* for preparation of wall paintings, which also seem to have been thicker than the majority of the identified and studied prehistoric threads (Andersson Strand, Nosch 2015: Appendix A). However, the clay sealing imprints may be considered as those of threads mainly on the grounds of their finesse, even though these threads had an alternative use beyond textile-making.

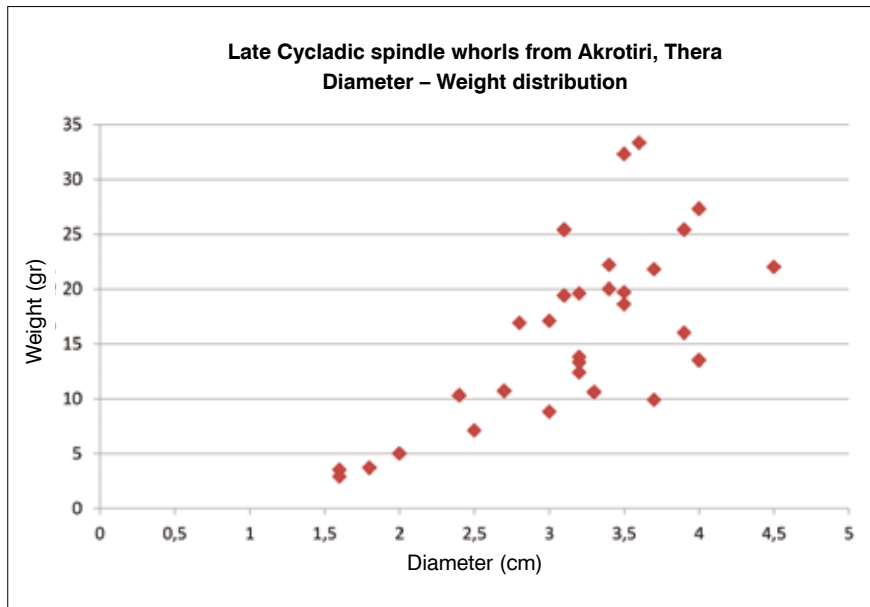


Fig. 5. Scatterplot of the diameter and weight values of spindle whorls from Late Cycladic Akrotiri.

‘industry’ as indicated by the tools discovered and examined so far.

But what types of products would have been produced with them? A perspective on the end products may be gained by experiments conducted by the CTR at the University of Copenhagen. Experimental spinning was conducted with replicas of prehistoric spindle whorls. Two replicas weighing respectively 8 and 18 g were used to spin wool fibres (Olofsson *et al.* 2015: 77). Woollen z-spun threads were produced with the use of these two different spindle whorls (Möller-Wiering 2015: 104). Spinning with an 8 g spindle whorl produced threads with a mean diameter of 0.3759 mm, while the use of an 18 g specimen resulted in threads with a mean diameter of 0.4582 mm (Möller-Wiering 2015: 107, Fig. 4.2.10). Spinning flax fibres with the same 8 g spindle whorl yielded slightly thinner threads with a mean diameter of 0.299 mm (Möller-Wiering 2015: 110).

The results of these experiments allow, by analogy, for a general correlation between the Theran wall painting imprints and the Akrotiri Late Cycladic spindle whorls. Given the width of their imprints, it may be hypothesised that the strings used by the painters had been spun with spindle whorls heavier than 18 g if the raw material was animal fibre and in particular wool. If the strings were made of flax, they might have required slightly heavier spindle whorls. The Akrotiri assemblage includes such heavy tools, but further experimentation is necessary to narrow down the spindle whorl size which can produce strings similar to those impressed on the wall paintings.

With regard to the clay sealing imprints, it is clear that these correspond to thread produced elsewhere,

since the sealings themselves are considered to have been imported to Akrotiri, as indicated by the macroscopic clay examination and characterisation. The exact locality of their production cannot be confirmed at the moment, but a Cretan origin has been suggested (as mentioned previously). Although prehistoric spindle whorls were found in several locations on Crete, it is generally accepted that they have been comparatively rare finds on this island (Militello 2007: 41; Burke 2010: 50). This observation has triggered several hypotheses about alternative thread production techniques which perhaps did not require the use of the spindle whorl (Tzachili 1997: 128). However, the clay sealing imprints with visible fibre twists suggest the use of spindles equipped with very light spindle whorls *versus*, for example, splicing. Assuming that the threads wrapped around the leather pieces, to which the clay sealings were attached, were spun on Crete, a survey of Cretan spindle whorls from localities compatible with the clay fabric of the sealings would potentially enable testing further hypotheses on the manufacture localities of those threads, and to revisit the current views on Cretan spinning practices. Again, on the basis of the CTR experiments, one could postulate the use of spindle whorls weighing between 8 and 20 g for the manufacture of threads with diameters ranging from 0.3 to 0.5 mm, while slightly heavier spindle whorls were supposedly used for the thicker threads which created an imprint 1 mm thick.

What is interesting is the fact that all of the threads wrapped around the examined sealings had the s direction, suggesting a consistent technical choice to twist in the counter-clockwise direction. If this is the primary twist, then this choice brings these presumably Cretan

Imprint material	Identification	Measured Feature	Width	Spin direction	Structure	Twist density
Plaster	Boxing Boys 1	Imprint	1.5 mm	z (negative)	Single ?	6 twists / cm
Plaster	Boxing Boys 2	Imprint	3 mm	z (negative)	Single ?	7 twists / cm
Plaster	Boxing Boys 3	Imprint	1.5 mm	z (negative)	Single ?	7 twists / cm
Plaster	Antelopes 1	Imprint	2 mm	z (negative)	Single ?	6 twists / cm
Plaster	Antelopes 2	Imprint	1.5 mm	z (negative)	Single ?	6-7 twists / cm
Plaster	Antelopes 3	Imprint	1.5 mm	z (negative)	Single ?	6 twists / cm
Clay	A 8892	Cast of imprint	0.4-0.5 mm	s (positive)	Single ?	Non discernable
Clay	A 8913	Cast of imprint	0.6 mm	s (positive)	Single ?	Non discernable
Clay	A 8916	Cast of imprint	0.3 mm	s (positive)	Single ?	Non discernable
Clay	A 8939	Cast of imprint	1 mm	s (positive)	Single ?	5 twists / cm

Fig. 6. Technical features of spun products observed on the imprints and/or their casts.

threads closer to Egyptian spinning techniques (Barber 1991: 65). In this aspect, a comparison with the strings impressed on the Thera wall paintings becomes crucial. Unfortunately, it was not possible to confirm whether the wall painting imprints preserve the features of single-spun or plied strings. Accurate techniques of observation of the Thera string impressions, perhaps in the microscopic scale, would greatly enhance our understanding of their manufacturing technique and would render this comparison possible. If the fresco strings were proved to be S-plied, then the primary spin would be in the z direction, as is the case of the actual strings recovered at Akrotiri (Moulh  rat, Spantidaki 2006). On the contrary, if they proved to be s-spun, then the hypothesis of diverse techniques of spinning at the same locality would be corroborated.

### g) Concluding remarks

Akrotiri on Thera is one of the rare archaeological sites in the Aegean with exceptional preservation conditions. Due to its thick volcanic deposits which buried and sealed the site following the ‘Minoan’ explosion of the Santorini volcano in the 17<sup>th</sup> or 16<sup>th</sup> century BC, in some instances organic material has been found in relatively good condition. Among several organic finds, actual strings and ropes have been found as well (Michailidis, Angelidis 2006). Important as they may be, original strings and ropes are not recorded at most Aegean prehistoric sites, but with a combined methodology integrating tool analysis, imprints analysis, and original thread, string, or rope analysis it may be possible to disentangle the prehistory of the Aegean fibre crafts.

Especially the thread and string imprints analysis will prove a source of crucial comparative data, since these relics survive frequently in archaeological contexts.

In particular, the collection of metrological and technical data deriving from imprints (Fig. 6) can be useful for a series of experimental tests to correlate tools and products on the basis of methodologies developed by the CTR in Copenhagen. The examples of imprints presented in this paper show how this particular field of research allows for testing previous experimental work in order to gain a clearer picture of the applied technology. The discussed observations enable a first level of comparison between what was in all probability local Thera fibre products on the one hand, and Cretan threads on the other. This suggests a preliminary conclusion that the spindle technology was applied in both localities for production of high quality fibre products to be used beyond textile production. So, the imprints suggest the use of the spindle whorls and the sharing of a common basic technological tradition in the two neighbouring islands during the Neopalatial period, at least in the light of the sample presented. Not all aspects of this technology are discernible by the use of this method, at least not during this early stage. To address crucial questions, such as the dominant twist direction and angle, microscopic analytical methods and a larger imprint sample would be necessary.

Aegean Bronze Age textile production was undoubtedly an industry which absorbed most of the processed wool and flax, and much of the fibre craftsmanship was organised around this central axis of weaving cloth. However, fibre crafts addressed a much wider range of everyday needs in Bronze Age communities. Strings and

ropes were essential for traditional applications such as binding and tying materials together. The sealing imprints discussed in this paper are only a single manifestation of such practices and other examples may also be mentioned. The cast of a bed from Akrotiri demonstrates how strings were used for its manufacture, while strings were also used to make the grid upon which the 'mattress' of the bed was to be laid (Gerontas 2004). A most ingenious use of strings, however, is demonstrated by the case of the wall painting imprints. The linear horizontal boundaries created by the string impressions may be regarded as an early form of a *canon*, a ruler to measure, arrange, and organise space. It is certain that this was a widely diffused artisanal technique in the Aegean Bronze Age since string impression was also used a few centuries later in the decoration of the floor of the Megaron at Mycenaean Pylos (Egan 2015). While the measuring function of the strings is not as straightforward as their organising function in the case of the wall paintings, an Akrotirian clay Middle Cycladic loom weight provides an opportunity to consider the former function: a thick string was pressed on the clay before this textile tool was fired, exactly in the middle of its sur-

face and along its vertical axis. The accurate position of the string imprint with regard to the shape of the loom weight's surface indicates its intentional contact with the clay. It is possible that the string was attached to the still unfired loom weight in order to 'measure' its dimensions and transfer them on other pieces of clay in a process of mass manufacture of identical loom weights (Vakirtzi forthcoming b).

Fibre crafts, and in particular the laborious task of producing threads and strings, were entangled with many different aspects of technical and artisanal activities in the Aegean Bronze Age. A careful comparative examination of imprints has a potential to provide insights not only about fibre technology but also aspects of material and non-material culture which may be otherwise archaeologically undetected. In the case of strings and ropes, this paper highlights the way that their imprints may be integrated into research methodologies as a crucial category of archaeological evidence, suitable for the investigation of interregional transfer of technological know-how, as well as for exploration of cognitive achievements, such as the organisation of space in Bronze Age art.

## Bibliography:

- Adovasio J.M., Soffer O., Klima B. 1996 Upper Palaeolithic fibre technology: interlaced woven finds from Pavlov I, Czech Republic, 26,000 years ago, *Antiquity* 70, 526–534.
- Andersson Strand E. 2015 The basics of textile tools and textile technology – from fibre to fabric, (in:) E. Andersson Strand, M.-L. Nosch (eds), *Tools, Textiles and Contexts. Investigating Textile Production in the Aegean and Eastern Mediterranean Bronze Age*, Ancient Textiles Series 21, Oxford, Philadelphia, 39–60.
- Andersson Strand E., Nosch M.-L. (eds) 2015 *Tools, Textiles and Contexts. Investigating Textile Production in the Aegean and Eastern Mediterranean Bronze Age*, Ancient Textiles Series 21, Oxford, Philadelphia.
- Asimenos K. 1978 Technological observations on the Thera wall paintings, (in:) C.G. Doumas (ed.), *Thera and the Aegean World II. Proceedings of the Second International Scientific Congress, Santorini, Greece, August 1978*, Vol. I, London, 571–577.
- Barber E.J.W. 1991 *Prehistoric Textiles. The Development of Cloth in the Neolithic and Bronze Ages with Special Reference to the Aegean*, Princeton.
- Barber E.J.W. 1994 *Women's Work. The First 20,000 years. Women, Cloth and Society in Early Times*, New York.
- Boulotis C. 1998 Les documents en Linéaire A d'Akrotiri (Thera): remarques préliminaires, *Bulletin de Correspondance Hellénique* 122, 407–411.
- Broodbank C. 2000 *An Island Archaeology of the Early Cyclades*, Cambridge.
- Burke B. 2010 *From Minos to Midas: Ancient Cloth Production in the Aegean and in Anatolia*, Ancient Textiles Series 7, Oxford, Oakville.
- Crowfoot G.M. 1931 *Methods of Hand Spinning in Egypt and the Sudan*, Bankfield Museum Notes 12, Halifax.
- Doumas C.G. 1992 *The Wall Paintings of Thera*, Athens.
- Doumas C.G. 2000 Seal impressions from Akrotiri, Thera: a preliminary report, (in:) W. Müller (ed.), *Minoisch-Mykenische Glyptik. Stil, Ikonographie, Funktion. V. Internationales Siegel-Symposium, Marburg, 23–25 September 1999*, Corpus der minoischen und mykenischen Siegel Beiheft 6, 57–65.

- Egan E. 2015 Working within the lines: Artists' grids and painted floors at the Palace of Nestor, (in:) S. Lepinski, S. McFadden (eds), *Beyond Iconography. Materials, Methods and Meaning in Ancient Surface Decoration*, Archaeological Institute of America, Boston, 187–204.
- Evans J.D., Renfrew C. 1968 *Excavations at Saliagos near Antiparos*, London.
- Georma F. 2009 *Oi toichografies apó to Ktírio V toy proístorikoý oikismoý Akrotírioy Thíras* / *The wall paintings of Building Beta at the prehistoric site of Akrotiri, Thera* (in Greek), unpublished PhD thesis, University of Ioannina.
- Gerontas A. 2004 Exposure and conservation of beds in Akrotiri, Thera, *ALS. Periodical Publication of the Society for the Promotion of Studies on Prehistoric Thera* 2, 47–52.
- Gleba M. 2017 Tracing textile cultures of Italy and Greece in the early first millennium BC, *Antiquity* 91(359), 1205–1222.
- Gleba M., Mannering U. (eds) 2012 *Textiles and Textile Production in Europe: From Prehistory to AD 400*, Ancient Textiles Series 11, Oxford, Oakville.
- Grömer K., Kern D. 2010 Technical data and experiments on corded ware, *Journal of Archaeological Science* 37, 3136–3145.
- Hallager E. 1996 *The Minoan Roundel and Other Sealed Documents in the Neopalatial Linear A Administration*, Aegaeum 14, Liège, Austin.
- Hardy K. 2008 Prehistoric string theory. How twisted fibres helped to shape the world, *Antiquity* 82, 271–280.
- Karnava A. 2008 Written and stamped records in the Late Bronze Age Cyclades: the sea journeys of an administration, (in:) N. Brodie, J. Doole, G. Gavalas, C. Renfrew (eds), *Horizon. Opiζov. A Colloquium on the Prehistory of the Cyclades*, McDonald Institute Monographs – Stavros Niarchos Foundation, Cambridge, 377–386.
- Karnava A. 2018 *Seals, Sealings and Seal Impressions from Akrotiri in Thera*, Corpus der minoischen und mykenischen Siegel Beiheft 10, Heidelberg.
- Michailidis I., Angelidis P. 2006 Conditions of preservation of organic materials of vegetal provenance in the prehistoric settlement at Akrotiri, *ALS. Periodical Publication of the Society for the Promotion of Studies on Prehistoric Thera* 4, 61–81.
- Militello P. 2007 Textile industry and Minoan palaces, (in:) C. Gillis, M.-L. Nosch (eds), *Ancient Textiles. Production, Craft and Society, Proceedings of the First International Conference on Ancient Textiles, Held at Lund, Sweden, and Copenhagen, Denmark, 19–23 March 2003*, Ancient Textiles Series 1, Oxford, 36–45.
- Möller-Wiering S. 2015 External examination of spinning and weaving samples, (in:) E. Andersson Strand, M.-L. Nosch (eds), *Tools, Textiles and Contexts. Investigating Textile Production in the Aegean and Eastern Mediterranean Bronze Age*, Ancient Textiles Series 21, Oxford, Philadelphia, 101–118.
- Moulhérat C., Spantidaki Y. 2008 Première attestation de la laine sur le site protohistorique d'Akrotiri à Thera, (in:) C. Alfaro, L. Karali (eds), *Vestidos, Textiles y Tintes. Estudios sobre la producción de bienes de consumo en la Antigüedad. Actas del II Symposium Internacional sobre Textiles y Tintes del Mediterráneo en el mundo antiguo (Atenas, 24 al 26 de noviembre, 2005)*, PURPUREAE VESTES II. *Textiles and Dyes in Antiquity*, Valencia, 37–42.
- Olofsson L., Andersson Strand E., Nosch M.-L. 2015 Experimental testing of Bronze Age textile tools, (in:) E. Andersson Strand, M.-L. Nosch (eds), *Tools, Textiles and Contexts. Investigating Textile Production in the Aegean and Eastern Mediterranean Bronze Age*, Ancient Textiles Series 21, Oxford, Philadelphia, 75–100.
- Panagiotakopulu E. 2000 Butterflies, flowers and Aegean iconography: a story of silk and cotton, (in:) S. Sherratt (ed.), *The Wall Paintings of Thera: Proceedings of the First International Symposium: Petros M. Nomikos Conference Centre, Thera, Hellas, 30 August – 4 September 1997*, Athens, 585–592.
- Panagiotakopulu E., Buckland P.C., Day P., Doumas C., Sarpaki A., Skidmore P. 1997 A lepidopterous cocoon from Thera and evidence for silk in the Aegean Bronze Age, *Antiquity* 71, 420–429.
- Pini I. 1983 Neue Beobachtungen zu den tönernen Siegelabdrücken von Zakros, *Archäologischer Anzeiger*, 559–572.
- Rast-Eicher A. 1997 Tessuti dell'età di Bronzo in Europa, (in:) M. Bernabó Brea, A. Cardarelli, M. Cremaschi (eds), *Le Terremare. La più antica civiltà padana*, Milan, 545–553.
- Rast-Eicher A. 2005 Bast before wool: the first textiles, (in:) P. Biechler, K. Grömer, R. Hofmann-de Keijzer, A. Kern, H. Reschreiter (eds), *“Hallstatt Textiles” – Technical Analysis, Scientific Investigation and Experiment on Iron Age Textiles*, British Archaeological Reports International Series 1351, Oxford, 117–135.
- Sarpaki A. 1992 Provlimatikí kai stóchoi tīs archaiovotanikís melētīs toy Akrotírioy / The study of the palaeoethnobotanical material from Akrotiri, Thera and its aims, (in:) C.G. Doumas (ed.), *Akrotíri Thíras, Eikosi Chrónia Éreynas (1967-1987)*, *Efimerída Athínai*, 19 Dekemvrioy 1987 (in Greek), Athens, 149–155.

- Shaw M.C. 2003 Grids and other drafting devices in Minoan and other Aegean wall painting. A comparative analysis including Egypt, (in:) K.P. Foster, R. Laffineur (eds), *METRON. Measuring the Aegean Bronze Age. Proceedings of the 9<sup>th</sup> International Aegean Conference / 9<sup>e</sup> Rencontre égéenne internationale, New Haven University, 18–21 April 2002*, Aegaeum 24, Liège, Austin, 179–189.
- Skals I., Möller-Wiering S., Nosch M.-L. 2015 Survey of archaeological textile remains from the Aegean and Eastern Mediterranean, (in:) E. Andersson Strand, M.-L. Nosch (eds), *Tools, Textiles and Contexts. Investigating Textile Production in the Aegean and Eastern Mediterranean Bronze Age*, Ancient Textiles Series 21, Oxford, Philadelphia, 61–74.
- Spantidaki Y., Moulhérat Ch. 2006 Klōstés, spággoi, schoiniá sti Santorínī / Threads, strings, ropes at Santorini, (in:) *Proceedings of the 2<sup>nd</sup> International Conference on Ancient Greek Technology, Athens 17–21 October 2005* (in Greek), Athens, 284–289.
- Spantidaki Y., Moulherat Ch. 2012 Greece, (in:) M. Gleba, U. Mannering (eds), *Textiles and Textile Production in Europe: From Prehistory to AD 400*, Ancient Textiles Series 11, Oxford, Oakville, 185–200.
- Trantalidou K. 2001 Zōotechnía kai oikonomía sto Akrōtīri / Animal Husbandry and Economy at Akrotiri (in Greek), (in:) I.M. Danezis (ed.), *Santorinī. Thīra, Thirasia, Aspronisi, Ifaisteia*, Athens, 193–204.
- Trantalidou K. 2008 E Archaiozōologikí éreyna stīn anaskafí toy Akrōtīrioy. O zōikós kósmos stīn kathimerinī zōī kai stīn ideología / Archaeozoological research at Akrotiri excavations. The animal world in every day life and in ideology (in Greek), *ALS, Periodical Publication of the Society for the Promotion of Studies on Prehistoric Thera* 6, 26–69.
- Tzachili I. 1990 All important yet elusive: looking for evidence of cloth making at Akrotiri, (in:) D.A. Hardy, C.G. Dumas, J.A. Sakellarakis, P.M. Warren (eds), *Thera and the Aegean World III, Proceedings of the Third International Scientific Congress, Santorini 3–9 September 1989, Volume I: Archaeology*, London, 380–389.
- Tzachili I. 1997 *Yfantikí kai yfantres sto Proistorikó Aigaio 2000–1000 p.Ch. / Weaving and Weavers in the Prehistoric Aegean, 2000–1000 BC* (in Greek), Heraklion.
- Tzachili I. 2007a Sfondýlia / Spindle whorls, (in:) C.G. Dumas (ed.), *Akrōtīri Thīras. Dytikí Oikía. Trápezes – Líthina – Metállina – Poikíla* (in Greek), Library of the Athens Archaeological Society 246, Athens, 259–261.
- Tzachili I. 2007b Weaving at Akrotiri, Thera. Defining cloth-making activities as a social process in a Late Bronze Age Aegean town, (in:) C. Gillis, M.-L. Nosch (eds), *Ancient Textiles. Production, Craft and Society, Proceedings of the First International Conference on Ancient Textiles, Held at Lund, Sweden, and Copenhagen, Denmark, 19–23 March 2003*, Ancient Textiles Series 1, Oxford, 190–196.
- Vakirtzi S. 2012 Akr 8794: A miniature artefact from Akrotiri, Thera, and the “whorl or bead” question in light of new textile evidence, (in:) M.-L. Nosch, R. Laffineur (eds), *KOSMOS. Jewellery, Adornment and Textiles in the Aegean Bronze Age, Proceedings of the 13<sup>th</sup> International Aegean Conference, University of Copenhagen, Danish National Research Foundation’s Centre for Textile Research, 21–26 April 2010*, Aegaeum 33, Leuven, Liège, 215–218.
- Vakirtzi S. 2015 *Ī nīmatoyrgía sto Aigaio katá tīn epochí toy Chalkoj mēsō tis paroyśias tōn sfondyliōn stis archaiologikés théseis: melēti tis typologías, tōn leitoyrgikōn dynatotītōn kai tis diasporás tōn exartīmātōn toy adrachtioy poy vrēthikan se oikismoys kai nekrotafeía / Yarn production in the Aegean Bronze Age. A study of typology, functionality and distribution of spindle whorls found in settlements and cemeteries* (in Greek), unpublished PhD thesis, University of Crete.
- Vakirtzi S. forthcoming a Sfondýlia apó tis prosfátes anaskafés / Spindle whorls from the recent excavations, (in:) C.G. Dumas (ed.), *Akrotiri, Thera, Forty Years of Research. Proceedings of a Scientific Meeting, Athens 2007* (in Greek), Athens.
- Vakirtzi S. forthcoming b Middle Cycladic loomweights and spindle-whorls, (in:) I. Nikolakopoulou (ed.), *Akrotiri, Thera. Middle Bronze Age. Pottery and Stratigraphy*, The Library of the Archaeological Society at Athens, Athens.
- Vakirtzi S. forthcoming c Fiber economy and technology at Neolithic Ftelia, Mykonos, *Mediterranean Archaeology and Archaeometry* 17(5).
- Weingarten J. 1983 The use of the Zakro sealings, *Kadmos* 22, 8–13.