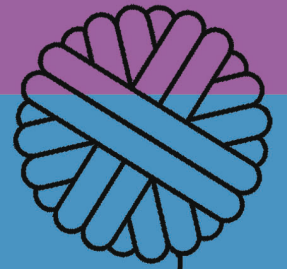


N°  
67

# ARCHAEOLOGICAL TEXTILES REVIEW



2025 issue

# Archaeological Textiles Review

ATR is published by the Friends of ATN, and hosted by the Centre for Textile Research in Copenhagen.

Editors:  
Karina Grömer  
Mary Harlow  
Jane Malcolm-Davies  
Ulla Mannering  
Kayleigh Saunderson  
Elsa Yvanez

Scientific committee:  
Johanna Banck-Burgess, Germany  
Christina Margariti, Greece  
Claudia Merthen, Germany  
Heidi Sherman, US  
Tereza Štolcová, Slovakia

Cover: Charlotte Rimstad  
Textiles on roman mail armour from Dura Europos  
(Image: Martijn Wijnhoven)

Layout: Karina Grömer and  
Kayleigh Saunderson,  
Natural History Museum Vienna

Print: Campus Print,  
University of Copenhagen

To purchase a printed copy of the latest *Archaeological Textiles Review*, please visit:  
<https://www.webshophum-en.ku.dk/shop/archaeological-textiles-664s1.html>

Visit [www.atnfriends.com](http://www.atnfriends.com) to learn more about the organisation.

ISSN 2245-7135

# Contents

## Editorial 2

---

## Reflections

---

- The road into the textile world: a long journey** 3  
Ulla Lund Hansen

## Articles

---

- Threads of warfare: textiles in Roman scale armour** 9  
Martijn A. Wijnhoven and Karina Grömer

- The Bryndum burial ground in Denmark: news on Viking Age women's clothing** 24  
Ulla Mannering, Michael Alrø Jensen, Lise Ræder Knudsen, Irene Skals and Ina Vanden Berghe

- A blue pile textile dating to the Viking Age from Saaremaa, Estonia** 42  
Riina Rammo, Krista Wright, Ina Vanden Berghe, Alexia Coudray and Riikka Räisänen

- ATR-FTIR spectroscopy analysis of mineral-preserved textiles from Viking Age women's graves in Vinjefjord, Norway** 54  
Elizabeth E. Peacock and Thea P. B. Christophersen

- Beyond the *tirāz*: ninth to 13th centuries domestic textile production in al-Andalus** 73  
José María Moreno-Narganes

- Medieval latrine textiles from Rådhusgaten in Tønsberg, Norway** 92  
Sunniva Wilberg Halvorsen

- Twill on the warp-weighted loom: reconsidering double-notched supports** 108  
Katherine Larson, Marta Kløve Juuhl and Monika Ravnanger



## Projects

---

**The Pharaonic Textiles database:  
a new tool for recording archaeological textiles from Egypt** 121  
Chiara Spinazzi-Lucchesi and Elsa Yvanez

**The TransTexTec Exploratory Project: exploring transitions in textile technologies  
and economies in southern Portugal (2200–700 BCE)** 123  
Francisco B. Gomes, Catarina Costeira, Ricardo Basso Rial, Nelson Almeida,  
Cleia Detry, Linda Melo, Eduardo Porfírio, Sérgio Gomes and Carina Nunes

**Iron Age asbestos strings found in eastern Switzerland** 134  
Antoinette Rast-Eicher

**Textile research in the Croatian Science Foundation's project  
*Creating European Identities*** 136  
Julia Katarina Fileš Kramberger, Margarita Gleba,  
Karina Grömer and Hrvoje Potrebica

**The A3TEX research centre: archaeology and archaeometry of  
ancient textiles at the Sapienza University of Rome** 143  
Francesca Coletti

**The development of motif and technique in early  
medieval north European tablet weaving** 147  
Georgia Gould

**Updating knitting history: a connection between Egypt and Armenia?** 154  
Irene Waggener

**Conferences** 160

---

## Obituaries

---

Noémi Speiser 1926–2025 174

Elizabeth Wincott Heckett 1934–2025 176

**Resources: recent publications and news** 179

---



Dear Readers,

Welcome to the 67th issue of *Archaeological Textiles Review* in which we bring exciting news about Viking Age and early medieval textiles, specialist analytical techniques and experimental work. The section on projects is again filled with really interesting initiatives. In this issue, it is the Danish archaeologist and Emerita, Ulla Lund Hansen, who reports about her experiences in textile research. Unfortunately, we also bring the obituaries of two well-known and important textiles researchers, Noémi Speiser and Elisabeth Wincott Heckett. However, reading about their research and scientific impact is enlightening, and this is definitely an important way to honour our late colleagues.

It is now four years since we upgraded our homepage, where past issues can be downloaded free. The editorial group has decided to initiate further changes for ATR. Ever since the publication of ATN was taken over by an editorial team from the Centre for Textile Research (CTR) at the University of Copenhagen in Denmark in 2008 and later transformed into a fully open-source digital publication in 2019, the society of ATN Friends has funded the web hosting and domain, from which the issue is distributed. However, the current complexity of official society rules and the exceptionally high annual banking fees mean that this way of working is not viable in the long term. Therefore, the editorial team has decided that the journal will move to the online publishing platform Tidsskrift.dk hosted by the Royal Danish Library in Copenhagen. We have already signed a contract and in 2026 we will begin the design of the

new ATR journal platform and start uploading back issues.

In spring 2026, the editorial team will meet in Copenhagen for an introductory course on the use of the platform editorial system. We will gradually start using the editorial service for the journal and plan to use the system fully in 2027 for the publication of ATR 69.

We hope that the editorial system will help the publishing process and give authors more transparency in the work on their texts. We also hope that readers will appreciate the new platform and the fact that the Royal Library will ensure the survival of all your important work for the future.

Please keep sending articles in good time for our annual deadlines, and please take great care to conform to the *Guidelines for Authors*. The deadline for articles for each issue is the 1 May. We need project reports preferably before the end of June, but we can accept conference reports right after conferences finish, if they are held no later than 30 November. The same deadline applies to all other announcements.

It is still possible to order a printed copy of any of the journals from the web shop at the University of Copenhagen in Denmark ([www.webshophum-en.ku.dk/shop/archaeological-textiles-664s1.html](http://www.webshophum-en.ku.dk/shop/archaeological-textiles-664s1.html)).

Please do enjoy ATR 67 and spread the word about it. The ATR editorial team wishes you a colourful and super exciting new academic year 2026.

*The Editors*



Katherine Larson, Marta Kløve Juuhl and Monika Ravnanger

# Twill on the warp-weighted loom: reconsidering double-notched supports

## Abstract

In the 1970s, five wooden artifacts were extracted from the medieval layers in Trondheim (Norway). These implements, 30–34 cm in length with a notch at one end and in the middle, were interpreted as attachments for the warp-weighted loom, a factor of keen interest to textile historians. Even before these implements were documented, a theory developed for how “double-notched heddle-rod supports” could be used for weaving 2/2 twill. Other methods for weaving twill on this loom have been proposed over time, with and without reference to the Icelandic method drawn from 18th to 19th century records, but no other interpretation for how double-notched supports may have been used has been presented. In this research, the role of these supports is reimagined, and an alternative method is proposed for how 2/2 twill may have been woven. It is as effective, and more straightforward and intuitive than the previously proposed method.

**Keywords:** Warp-weighted loom, twill, heddle-rod supports, loom technology, medieval weaving

## Introduction

The warp-weighted loom was a major element of European weaving technology for thousands of years. The primary products of this loom were plain weave and the slightly more complex twill. Thanks to Marta Hoffmann’s ground-breaking study, which documented the few remaining warp-weighted loom practitioners in Norway and Finland, the method by which plain weave was woven on this loom in northern Europe is well understood (Hoffmann 1964) (fig. 1). The loom was no longer used to produce twill by the 20th century, and therefore the exact method by which this other major structure was woven is less clear. Evidence survived from Iceland in the form of late 18th century drawings depicting twill in progress on the loom (fig. 2), and in late 19th century letters from two elderly women who remembered weaving twill on the warp-weighted loom in their youth. While

Fig. 1: The warp-weighted loom set up for plain weave in Hordaland (Norway), as documented by Marta Hoffmann in 1956. Evident in the developing weave are several traditional hand-selection techniques that were commonly woven in a plain-weave setup (Image: Per Gærder, Norsk Folkemuseum)



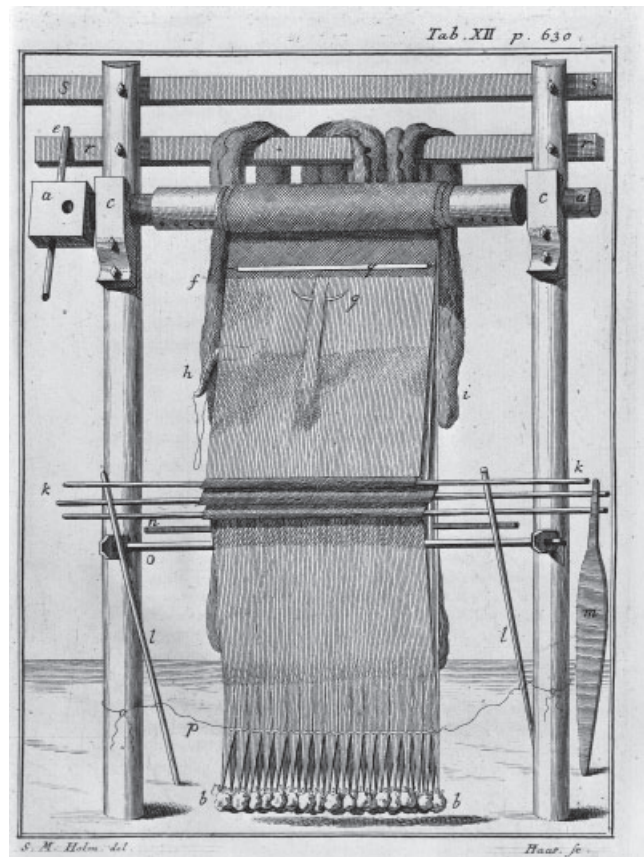


Fig. 2: Twill weaving on the Icelandic loom, as published in a 1780 volume by Olaus Olavius, now in the collection of the Royal Danish Library (Image: Norsk Folkemuseum)

not as detailed as Hoffmann's documentation of a living tradition, the latter information, first published in the yearbook of the Icelandic Archaeological Society (Þórðarson 1914), was summarised in Hoffmann's treatment of the warp-weighted loom (Hoffmann 1964, 114–140).

Among the details recorded by Icelandic sources were several important elements for weaving 2/2 twill. Similar to the method documented for plain weave, the loom was set up with a "natural shed", composed of two consecutive warp threads in front of the fixed shed rod (the forward layer), followed by two consecutive warps behind the shed rod (the back layer), thus creating one of 2/2 twill's four sheds. The remaining three sheds were each controlled by one of three heddle rods, with each heddle pulling forward two neighbouring warp threads. The setup of the Icelandic loom further differed from those Hoffmann had observed in Norway in the type of slanted brackets (*meiðmar*) that held the heddle rods in the open position to form a shed. Whether all of these elements were unique to Iceland or had once been common elsewhere in Europe is not known.

Over the years several methods other than that reported in Icelandic sources have been proposed for how 2/2 twill may have been woven on the warp-weighted loom. These methods fall into two basic categories: those that break completely with the Icelandic method by dispensing with the shed rod and the natural shed it creates, enclosing a



single warp thread in each heddle, and dividing the warp into four layers that are separately weighted (Schlabow 1952; 1976; Schierer 2005; Grömer 2016) (fig. 3a); and those that follow part of the Icelandic method by utilising the natural shed formed by the shed rod and enclosing two warp threads in each heddle, but employing heddle-rod supports



Fig. 3: Methods for weaving 2/2 twill using one or two warps per heddle and a varying number of single-notched support pairs: a) proposed method for weaving the Thorsberg mantle: one warp per heddle, four support pairs, four heddle rods (after Schlabow 1952); b) weaving sailcloth at the Viking Ship Museum: two warps per heddle, three support pairs, three heddle rods (Image: Werner Karrasch, © Viking Ship Museum, Roskilde); and c) weaving diamond twill at the Lendbreen tunic exhibit, Norsk Fjellmuseum: two warps per heddle, two support pairs, three heddle rods (Image: Randi Andersen, Osterøy Museum)



with single notches similar to those that survived in Norway and Finland, using variously one, two or three pairs of supports (Hoffmann 1964; Hansen 1978; Nørgård and Østergård 1994; Walton Rogers 2007; Hákonardóttir et al. 2016) (fig. 3b and fig. 3c).

In the 1970s, the discovery of five small wooden artefacts in the medieval layers of Trondheim (Norway) made a further contribution to the question of how twill was woven. These implements, 30–34 cm in length with a notch at both the midpoint and one end, were interpreted as attachments for the warp-weighted loom (Nordeide 1994, 230) (fig. 4). Such implements, for which a use was theorised even before their discovery (Haynes 1975), formed the basis for a third twill-weaving method that combined elements from both of the above-mentioned schools of thought. After further refinements (Batzer and Dokkedal 1992), this method, often identified as the four-weight-row method, has been included in numerous studies describing how twill was woven on the warp-weighted loom (Stærnøse Nielsen 1999; Andersson Strand 2010; 2015; Olofsson and Nosch 2015; Ulanowska 2017; Andersson Strand and Demant 2023).

The current research reconsiders this third method for

weaving twill, specifically its use of double-notched heddle-rod supports, and suggests an alternative interpretation for how these implements may have been used. It is based on the Icelandic method of enclosing two warps per heddle but utilises heddle-rod supports as attested in the Norwegian tradition rather than the slanted supports reported from Iceland. In the proposed method, double-notched supports solve a problem concomitant with enclosing two warp threads per heddle, namely occasional heddle jamming when opening a shed, and result in a weaving procedure that is both effective and more straightforward for 2/2 twill than that proposed. A comparison of these very different uses of double-notched supports follows.

It should be noted that the incorrect understanding of double-notched supports as an innovation that allowed the weaving of 2/1 twill on the warp-weighted loom (Crowfoot et al. 1992, 21; Nordeide 1994, 230; Øye 2016, 37) appears to have resulted from a conflation of experimental results presented in the seminal article on the four-weight-row method (Batzer and Dokkedal 1992). Both 2/2 and 2/1 twill methods are mentioned in that article, but as described there, 2/2 twill utilised double-notched supports, while 2/1 twill required only single-notched supports.

#### The four-weight-row method and double-notched supports

A review of how the four-weight-row method developed is instructive. The impetus for devising this new approach to twill was the observation of uneven warp tension when using the Icelandic two-weight-row system (Haynes 1975, 156). Haynes proposed a different system with changes to several main elements:

- Where the Icelandic method divided the warp evenly over the fixed shed rod, thereby creating one of 2/2 twill's four weaving sheds (the natural shed), Haynes divided the warp into four layers, with one placed in front of the shed rod and three behind.
- Where the Icelandic method included two warp threads in each heddle, Haynes suggested single warps per heddle, requiring the coordination of two warp groups to form each shed.
- Where the Icelandic method formed all but the natural shed in front of the forward-layer warp threads, Haynes proposed forming two sheds in front and two sheds behind the forward layer warp threads.
- Where Hoffmann's description of the Icelandic method indicated a row of weights tensioning



Fig. 4: Four double-notched heddle-rod supports (museum numbers N31160, N37223, N33146, N33433) discovered in medieval layers in Trondheim (Norway), now in the collection of NTNU University Museum, Trondheim (Image: Katherine Larson)

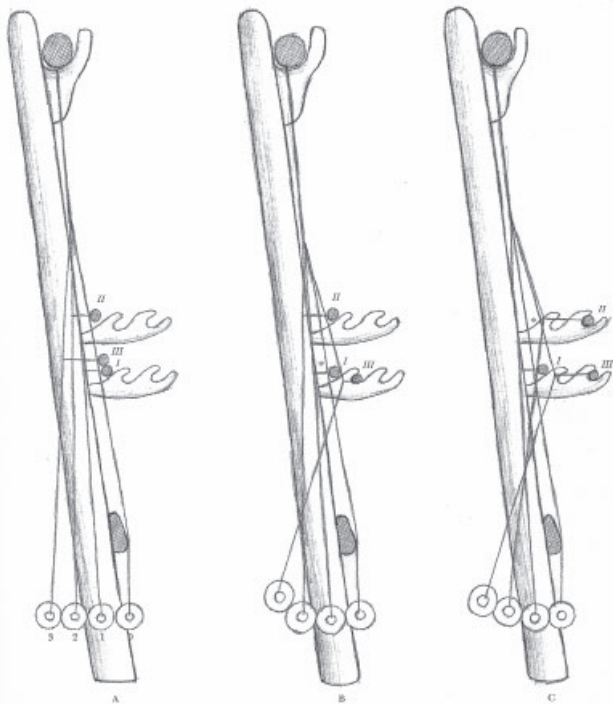


Fig. 5: Weaving twill with the four-weight-row method requires two pairs of double-notched supports, with sheds formed by combinations of two heddle rods or one heddle rod plus the fixed shed rod: a) heddle rods at rest; b) shed 2 formed with heddle rod III in inner notch; and c) shed 3 formed with heddle rods II and III in outer notches (Image: Anne Batzer, after Stærmosse Nielsen, 1999)

each of these two layers, Haynes proposed four separate weight rows that would provide equal tension to all warp layers.

Thus, Haynes combined elements from the two divergent approaches to twill weaving described above by dividing the warp into four separately weighted layers yet using the shed rod to hold forward only one of those layers. Haynes also added a further element to this proposed method. In forming two of the four sheds in this revised system, specifically those combining one of the back-layer warps with the single layer in front of the shed rod, Haynes noted that the back-layer warps only needed to be brought into alignment with the forward layer to open a shed at the back of the loom, and for this purpose a heddle-rod support fitted with a notch at midpoint would suffice. In addition, these midway notches reduced the tendency for back-layer weight rows, when pulled forward, to diminish shed sizes by pushing forward on neighbouring weight rows. Double-notched supports, with a notch at one end and in the middle, were thus envisioned as a way to address these two issues in the proposed new method.

Further experimentation with Haynes' proposed method by the Historical-Archaeological Research Centre in Lejre (Denmark) resulted in a slightly modified version of Haynes' method, with several refinements that are now considered standard (Batzer and Dokkedal 1992) (fig. 5):

- Where Haynes had used three pairs of heddle-rod supports (two with double notches), it was realised that only two pairs were required (both with double notches).
- Where Haynes had suggested a revision of the top-to-bottom order in which heddle rods were arranged (I, III, II rather than the more intuitive I, II, III), the revised order called for the upper pair of supports to hold heddle rod II and the lower pair to hold heddle rods I and III.
- Where Haynes made no mention of heddle size, varying heddle sizes were suggested to improve shed formation: heddle rod I – 5.5 cm; II – 8 cm; III – 7 cm.
- In a later description of this method, a further refinement was noted: the importance of sloping the height of weight rows in the back three layers to keep them from riding up on each other as they were pulled forward (Olofsson and Nosch 2015, 124).

### Reimagining the purpose of double-notched supports

In comparing a twill method that proposed dispensing with the shed rod (Schlabow 1952), with that recorded for weaving twill in Iceland, Marta Hoffmann noted: "...the Icelandic method is both simpler and much more ingenious. It bears the mark of long use, and shows that this had reached a point of technical perfection that could hardly be improved upon" (Hoffmann 1964, 139). This statement must be taken to include all aspects of the Icelandic method, with the most obvious elements being the long warp and the unique method for supporting the heddle rods with slanted sticks. Yet despite these noticeable aspects, those features would seem to represent practical solutions when weaving twill. The less visually obvious, but possibly more important feature of the Icelandic twill method may be the practice of including two warp threads per heddle. The current research is based on the idea that enclosing two warp threads per heddle is an important element for weaving 2/2 twill, and in fact one uniquely suited to the warp-weighted loom's divided warp. The archaeological find of double-notched heddle-rod supports, interpreted as implements for the warp-weighted loom, implies that weave structures more complicated than plain weave were being woven, with



twill a likely candidate. From this it would follow that, at least in Trondheim, weavers may have controlled their twill shedding differently than in Iceland, using heddle rod supports with double notches rather than the Icelandic slanted supports. Accordingly, experiments in the current research were designed to determine how double-notched supports have been used to facilitate the weaving of 2/2 twill.

## Experimental methods

### Study design

The central problem addressed by this research was heddle jamming noted in specific circumstances when weaving twill with two threads per heddle. Heddles on the warp-weighted loom are only secured at the forward end, where they are attached to the heddle rod. The other end of the heddle is held more or less taut by tension on the weighted warp threads, but that tension changes as various heddle rods are pulled forward. In the current research, which utilised heddles tied in an open loop, heddle jamming was especially notable in the case of the middle heddle rod that controls all back-layer warp threads. When this heddle rod was pulled forward, heddles on the upper and lower heddle rods, each of which also contained one back-layer warp, no longer had warp tension holding them back and therefore became slack. Pulling forward heddle rod II past these now slack heddles led to heddle jamming as the back-layer warps attempted to pass through the forward layer, and sometimes to tangles between heddles and neighbouring warp threads when releasing the heddle rod. While these problems could be resolved by plucking apart tangles and tugging on the heddle rods to relieve jamming, this constant effort took time and could cause wear on the heddles and warp threads involved.

The current research therefore concentrated on the problem of heddle function as it might relate to double-notched heddle-rod supports. It should be noted that aspects of the warp itself, such as the use of sizing to improve heddle passage or the potential for achieving a suitable fabric density through fulling a less dense web, were not considered. Instead, a method for avoiding slack heddles was envisioned by using double-notched heddle-rod supports to provide a midway return point for the upper heddle rod after it opened a shed. The intended purpose was to hold these warps and their heddles taut to facilitate the passage of the middle heddle-rod warps. However, a preliminary assessment indicated that similar problems arose during the transition between the middle and lower heddle rods. Therefore double-notched supports were



Fig. 6: Test loom with three pairs of heddle-rod supports: two upper pairs had experimental double notches, lower pair had single notches; holes for moveable pegs in the experimental heddle-rod supports allowed flexibility in finding a suitable distance from the uprights for both inner and outer notches (Image: Monika Ravnanger, Osterøy Museum)

chosen for both the upper and middle heddle rods to test whether keeping each group of heddles taut after opening their respective sheds would improve the passage of subsequent groups of warp threads.

### Materials

Experiments were carried out using Hoelfeldt Lund single-ply wool yarn from the Nordic short-tailed sheep (*spælsau*). Two warps with different properties were tested at different warp densities. The first warp was z-spun, 4,500 m/kg, a mixture of underwool and outer wool (hair), with a higher percentage of underwool; it was woven at a density of 8 threads/cm and a weaving width of 60 cm. The second warp was s-spun, 5,250 m/kg, also a mixture of underwool and outer wool, with a higher percentage of outer wool. It was woven at a density of 12 threads/cm and a weaving width of 66 cm. Both warps were weighted on the loom at approximately 50 g/thread to provide sufficient tension.

### Loom setup and warping procedures

Experiments were conducted at Osterøy Museum



(Norway) and at a weaving studio in the Seattle area (United States). The looms were set up as follows:

- The warp was arranged in two evenly divided rows, with alternately two warp threads in front of the shed rod and two behind.
  - Experimental “double-notched” support pairs were created with holes at 2 cm intervals to receive small pegs, thus permitting heddle rod placement to be calibrated to heddle length and shed size.
  - Three pairs of heddle-rod supports were used, ordered I, II, III from top to bottom; the two upper pairs (heddle rods I and II) utilised the experimental double-notches, the lower pair (heddle rod III) required only single notches (fig. 6).
  - Both forward and back warp rows were divided into bundles and weights were attached to each row, providing a tension of 50 g/thread.
  - Heddles were tied to create the 2/2 twill structure, with two neighbouring warp threads enclosed in each heddle: heddle rods I and III were tied concurrently, each containing one forward- and one back-layer warp thread; heddle rod II was then tied between I and III, enclosing pairs of back-layer warps.
- All heddles were of equal length.
  - After heddle tying, warp threads in the back weight row were divided into two rows based on the warp division established by the heddles; the newly divided bundles in these rows were then tied with halved weight amounts to maintain the tension of 50 g/thread (this and the following point are elements of the Icelandic method described in the discussion section below).
  - The two back weight rows were joined together with a spacing chain that included four warp threads per loop, two from each row of weights.
  - All weight rows were tied at approximately the same height.
  - The front weight row was also divided into two rows, each with halved weight amounts, and warps were chained together in the same manner as the back row.

In determining appropriate notch distances on the experimental supports, the placement of heddle rod I was adjusted so that when held by the inner notches, the affected warp threads were slightly in front of the forward warp layer. This ensured that these heddles were taut for the passage of heddle rod II. For heddle



Fig. 7: Placement of the heddle rods to form the four 2/2 twill sheds, using double-notched supports for the upper two support pairs: a) shed 0 is open, all heddle rods at rest against the uprights; b) shed 1 is open, heddle rod I in outer notches; c) shed 2 is open, heddle rod I in inner notches and heddle rod II in outer notches; and d) shed 3 is open, heddle rods I and II in inner notches and heddle rod III in single notches (Images: Katherine Larson)



rod II, an inner notch distance that held affected warp threads approximately even with the forward warp layer was found to be sufficient (fig. 7). The distance to the outer notches of both pairs was determined by the desired shed size of approximately 6 cm. Thus, the upright-to-notch distances for the two pairs of supports were not the same, with heddle rod I notches being somewhat closer to the uprights than those of heddle rod II.

### Weaving procedures and findings

Weaving followed a regular pattern: a shed was opened to insert the weft, the shed was changed, the weft was beaten in, and the following weft inserted. Weaving order progressed from shed 0, the natural shed, through sheds 1, 2 and 3 by accessing heddle rods I, II and III. All heddle rods were pulled forward to the outer notches of a support pair to open their respective weaving sheds, but after use, heddle rods I and II were returned to the inner notches of

their supports before the next shed was opened. In contrast, after the weft was inserted in shed 3, heddle rod III was returned to rest against the uprights, followed by heddle rods II and I, thus again forming shed 0 with all three heddle rods at rest against the uprights (fig. 8).

Results were consistent when weaving at both 8 threads/cm and 12 threads/cm: the steps in weaving were straightforward, heddle jamming was not a factor, and sheds were clear, with the exception of several sticky warp threads evident in every shed, which required minimal clearing. There were no problems with uneven tension since both front and back layers were divided, thereby adequately tensioning the warp threads controlled by heddle rods I and III, and the spacing chain held the divided back weight rows together so that they travelled as one, causing no interference with each other.

Weaving twill in reverse order was also straightforward if slightly less intuitive. Accessing

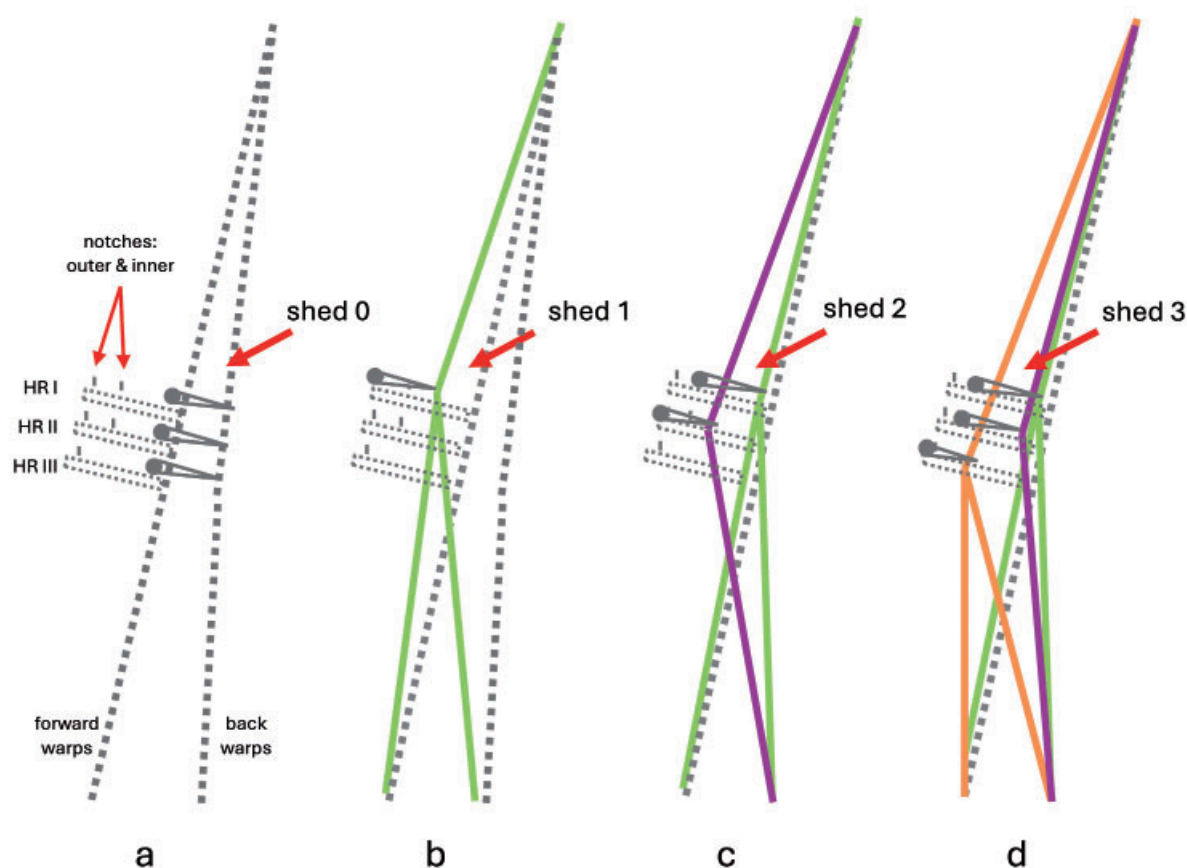


Fig. 8: Simplified view showing movement of the warp layers as heddle rods are manipulated to form sheds: a) all heddle rods at rest against the uprights for shed 0; b) heddle rod I placed in outer notches for shed 1; c) heddle rod I placed in inner notches, heddle rod II placed in outer notches for shed 2; and d) heddle rod II placed in inner notches and heddle rod III placed in single notches for shed 3 (Image: Katherine Larson)



sheds in the order 0, 3, 2, 1 required placing heddle rods I and II in their inner notches following the 0 shed, from which point these two heddle rods operated normally, that is they were pulled to their outer notches to open their respective weaving sheds.

#### *Comparison of single-notched support options with double-notched supports*

The use of single-notched supports for weaving twill likely represented a departure point from which the use of double-notched supports evolved. As noted above, the use of one, two and three single-notched support pairs had been suggested by past research, and therefore support-pair conformations were altered on the test warps to compare these combinations to each other and to the use of double-notched supports as proposed in the current research. Four options using single-notched supports were tested:

- Three pairs of single-notched supports, each pair holding a single heddle rod.
- Two support pairs holding two rods on the upper supports and one rod on the lower supports.
- Two support pairs holding one rod on the upper supports and two rods on the lower supports.
- One support pair holding the middle heddle rod and two pairs of pegs (above and below) holding the upper and lower heddle rods. All three heddle rods utilised the middle support pair's notches to open a shed.

It should be noted that the use of one pair of supports was the basis for Marta Hoffmann's twill experiment, referred to but not fully described in her book (Hoffmann 1964, 131–136). However, this method was clearly documented in her unpublished research notebook and therefore was included in these tests (Hoffmann 1952–1953) (fig. 9).

Problems were found across all four options upon opening and closing shed 2, in other words when bringing forward and releasing heddle rod II, which controlled pairs of back-layer warp threads. As noted above, when heddle rod II was pulled forward, heddles on rod I became slack and jammed when back-layer warp threads encountered the forward-layer warp, thereby blocking shed formation. After heddle rod II was placed in its notches, tugging on heddle rod I usually cleared these jams, and a shed, albeit obscured by many residual sticky warp threads, began to form. Shed 2 could then be fully cleared by pulling on heddle rod II again, or "overpulling" it from its already open position, to separate the sticky warps that remained. Although the slack heddles attached to heddle rod III, located below heddle rod

II, did bunch slightly in front of the forward warp layer, they usually did not jam or require tugging on that heddle rod to facilitate the clearing of shed 2. Upon closing shed 2 similar problems were experienced, with heddles attached to heddle rod I again becoming jammed or sometimes tangled with neighbouring warps, blocking the warp threads from assuming their at-rest positions. Tugging on heddle rod I cleared most of these jams, but occasional tangles between heddles and neighbouring warp threads had to be plucked apart by hand.

In contrast to the significant problems experienced with shed 2, in all four single-notched support-pair setups the opening and closing of sheds 1 and 3 was relatively trouble free. However minor heddle jams, especially in the transition between sheds 2 and 3, occasionally required tugging the heddle rods, and all sheds required clearing of sticky warp threads through a combination of overpulling the open heddle rods, strumming the warp threads and/or hand clearing individual sticky warps.

In comparison to all options using only single-notched supports, the use of double-notched supports for heddle rods I and II resulted in a weaving cycle with no heddle jamming or tangling with neighbouring warps. However, similar to all single-notched options, weaving with double-notched supports still required the clearing of a limited number of sticky warp threads in all sheds.

#### **Discussion**

##### *Questions regarding the four-weight-row method*

The perceived uneven tension in the Icelandic method, which was the instigating factor in Haynes' original proposal for using double-notched supports, was unfortunately based on incorrect information reported by Hoffmann. Her twill experiments, which were partially based on the Icelandic method, were performed several years before a discrepancy was noted in the original Icelandic source documents. In 1979, a careful rereading of the original Icelandic sources by weaver Sigríður Halldórsdóttir revealed that two details in the loom's setup had been overlooked: a division of the back weights into two rows that were then chained together, and the use of an additional floating rod to assist in separating the sheds (Guðjónsson 1985, 121). These elements resolved the tension problems noted by Haynes. Without knowledge of these refinements to the Icelandic method, Haynes' revisions represented effective, logical choices.

However, it should be noted that the newly designed



system addressed a difficulty in the Icelandic method that did not actually exist, and envisioned double-notched supports as a means to facilitate the functioning of this new system. Moreover, in solving the perceived tension problem and devising a new implement as part of that system, no consideration was given to the accompanying major changes from a known method, primarily dispensing with both the natural shed and the practice of enclosing two warp threads per heddle. Regarding possible methods for

weaving twill on the warp-weighted loom, Marta Hoffmann remarked: “everyone concerned with the technical aspects of textile production is well aware... that the same result can be achieved by various methods” (Hoffmann 1964, 139). It would seem that the system proposed by Haynes and the method that evolved from it underscores this statement.

An important element in the positive reception of the four-weight-row method has been the greater flexibility it affords in weaving a variety of different

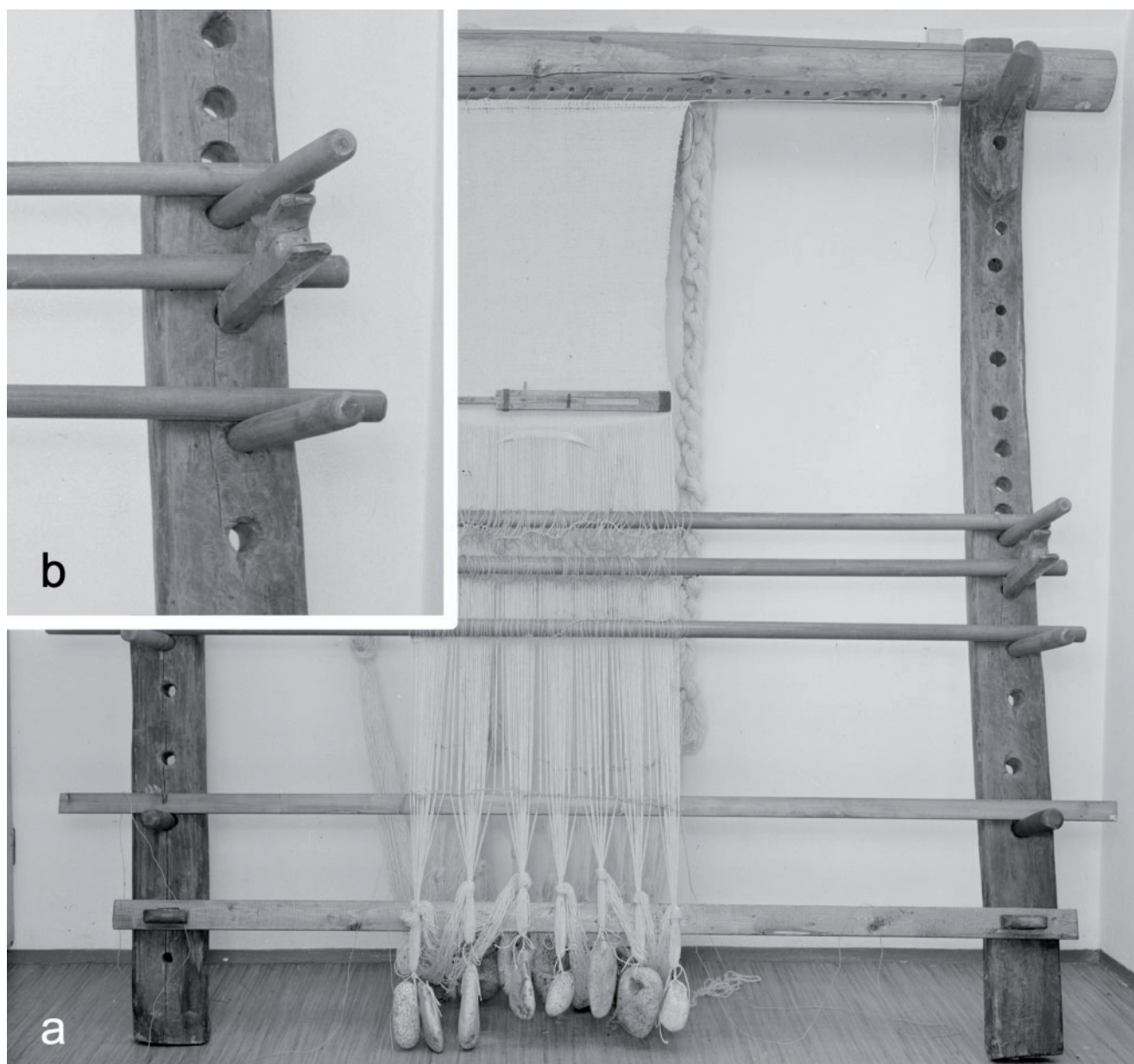


Fig. 9: Twill experiment on the warp-weighted loom conducted by Marta Hoffmann in 1952–1953: a) three heddle rods were held separately; and b) (detail) one pair of single-notched supports held the central heddle rod, upper and lower heddle rods rested on pegs, and all three heddle rods used the central pair of single-notched supports to open a shed (Image: Norsk Folkemuseum)



fabric structures, including “tabby, basket-weave, 2/2 and 3/1 twill and different floating lacings and pattern effects” (Batzer and Dokkedal 1992, 234). Such an expanded flexibility introduces the intriguing possibility that textiles once interpreted as coming from a more sophisticated production setting may have in fact been woven on the warp-weighted loom (Stærnøse Nielsen 1999, 96). Clearly the advantages derived from the four-weight-row method do increase the warp-weighted loom’s capability, especially when viewed with an inherent understanding of modern loom technology. As noted by Haynes, “Using the principles propounded in this article, with four warp systems and three heddle rods, all the weave plans which are possible on a modern four-shaft loom are technically feasible” (Haynes 1975, 164). In essence, this new system mirrors the flexibility of the modern treadle loom transferred into a system that utilises a divided warp.

The factor of warp separation may have a bearing on a further perceived advantage of the four-weight-row method: the capacity for weaving dense twills (Batzer and Dokkedal 1991, 151; Olofsson and Nosch 2015, 122). The separate layers of the four-weight-row method are theorised to confer this advantage, especially when the warp-weighted loom is compared to other early looms such as the two-beamed vertical or ground loom, both of which function with the warp in a single plane (Andersson Strand 2015, 54). However, concerning the issue of warp separation at the centre of this argument, the four-weight-row method is often distinguished from the Icelandic “two-weight-row” method (Olofsson and Nosch 2015, 120; Andersson Strand 2015, 54). On face value this appears to be an accurate distinction: the divided back weight rows of the Icelandic method are joined together by a spacing chain, visually forming a single back row of weights. But the chained-together weight rows nonetheless transmit their divided effect up the warp threads, providing tension results similar to completely separate rows. It is possible, then, that the four separate layers of the four-weight-row method are not necessary to achieve this density advantage. With elements of the Icelandic twill-weaving method as a basis, the loom’s characteristic two layers, divided but chained together, may confer a similar benefit from separation when weaving a denser twill warp, especially if that weaving is facilitated by the use of double-notched supports as proposed in the current research.

Despite the perceived advantages of the four-weight-row method, it is significant to note that problems with both heddles and shedding have been noted in a

recent comprehensive study employing this method (Andersson Strand and Demant 2023). For example, after attempts to stiffen the heddle material with wax, heddles still had a tendency to “curl against the layers of warp which they have to pass through when the shed was changed” (Andersson Strand and Demant 2023, 41). It was also noted that although weaving went “relatively smoothly,” finding a proper shed required “practice and attention... [since] each shed had to be worked differently”. This resulted from the need to coordinate two heddle systems to create each shed. It was further noted that shed openings, two of which were formed in front of the forward warp layer and two behind, appeared variously below, between and above the rows of heddles, and once identified, in some cases had to be pressed open and up into the weaving area (Andersson Strand and Demant 2023, 41–42). Aside from the “practice and attention” required to use this system, the four-weight-row method appears to suffer from the same problem as that addressed in this research, namely the impact on shedding by heddles held securely at only one end within the inherently mobile warp layers of the warp-weighted loom.

#### *Advantages of the proposed use of double-notched supports*

The use of double-notched supports proposed by the current research holds several advantages over the use of those implements in the four-weight-row method. First, the loom setup adheres to the only known practice for weaving twill, enclosing two warp threads per heddle, a system that ensures uniform alignment of warp threads for shed openings. It also uses three pairs of heddle-rod supports rather than two, a practice possibly supported by evidence of wear in three closely set holes on a surviving warp-weighted loom (Hoffmann 1964, 134). Furthermore, the simplicity of the proposed system contrasts markedly with the complexity of the four-weight-row method. In the proposed system, heddle rods are ordered and employed in a logical progression; heddles do not need to be of different lengths to form effective sheds since each shed is controlled by one heddle rod; there is no need to tie weight rows in a sloping orientation to avoid riding up on one other; and all sheds except the natural shed, which is clearly formed behind the shed rod, are unambiguously formed above the heddles at the front of the loom.

A recognised limitation of the current study regards the accuracy of materials, which can be a significant factor in attempting to replicate processes and products that were once woven on the warp-weighted



loom. This suggests that further experimentation is needed, similar to the study mentioned above, which was designed to meticulously replicate selected archaeological textiles (Andersson Strand and Demant 2023). With notable attention devoted to appropriate fibre selection, yarn spin and weight-row conformation, the 2/2 twill textile produced in that study closely resembled the original artefact. However, the weaving process that utilised the four-weight-row method seems to have been less successful. It is possible that revising the weaving method to the one suggested by the current research would facilitate similar future investigations, advancing the understanding of how twill may have been woven on the warp-weighted loom.

In assessing the two possible uses of double-notched supports under consideration, the more complicated four-weight-row method seems unlikely to have had very wide use. Supporting this suggestion is a comparison between two forms of diamond twills present in the archaeological record: those with symmetrically formed diamonds, often referred to as goose-eye twill, which may be taken to represent the greater flexibility in weave structures that the four-weight-row method makes possible, and those that are asymmetrical, typically referred to as broken diamond twill, in which the points of reversal are staggered (Emery 1966, 98). The broken diamond structure flows naturally from a warp that is divided into two equal parts, which is the basis for the two threads per heddle of the Icelandic method. This heddle-tying order can easily be altered to produce a broken diamond twill by tying two single-warp heddles at the points of reversal without disrupting the system in which single heddle rods open a shed, but it is not suited to tying heddles that enclose three neighbouring warps as required for a symmetrical diamond twill.

After evaluating perceived problems with the Icelandic method for weaving 2/2 twill, and describing how the newly envisioned four-weight-row method was capable of weaving a symmetrical, or regular diamond twill, Haynes remarks on this very issue, seemingly missing the point: "During the very long period over which diamond-patterned cloths were produced, the 'broken' form appears to have been of considerable importance; but evidence of the 'regular' version is extremely rare. The very length of time seems to discount fashion as the reason for this apparently overwhelming preference; although almost certainly related to the technology of the loom employed, the explanation remains obscure."

If the single-warp-per-heddle system of the Haynes

method had been widespread, would broken diamond twill have remained the norm for such a "very long period"?

#### *A lack of uniformity in weaving practices?*

A Faroese expression, "*Nu er ikki beint a midskaftid*" (now it's not right with the middle shaft), likens problems with the middle heddle rod to disagreements arising between people (Broholm and Hald 1935, 305). This saying has been taken to mean that, "the most difficult shed to get right was the one controlled by the middle rod" (Hoffmann 1964, 150). The jamming and tangling noted in the current research when weaving solely with single-notched supports bears out this analogy. This expression, then, may be taken to indicate two things: first, that twill was warped with two threads per heddle, a practice entirely in keeping with the extensive presence of broken diamond twill in archaeological textiles; and second, that use of solely single-notched supports, with their concomitant heddle problems, was a common practice.

Marta Hoffmann documented different practices among warp-weighted loom weavers in various cultural settings: use of a woven starting border among the Sami in north Norway, use of a weaving sword to beat in the weft in southwest Norway, and weaving from the back of the loom among the Sami in northern Finland, to name a few. Given this lack of uniformity, it is possible that when weaving twill, the solution to slack heddles proposed in this research may have been limited to medieval Trondheim. Or instead, it may indicate that innovations in weaving techniques were slow to spread and/or did not spread evenly. Medieval Trondheim offers one small window into past twill weaving practices, as does the saying from the Faroe Islands. The purpose of this research has been to interpret the possible use of double-notched supports found in Trondheim. How widespread such usage may have been is an open question.

#### **Conclusion**

Enclosing two warp threads per heddle is an intriguing aspect of the Icelandic method, allowing each of 2/2 twill's four sheds to be formed easily and evenly, with one heddle rod or the fixed shed rod controlling each. However and whenever this idea arose, it is uniquely suited to weaving this important type of cloth on the warp-weighted loom, and it represents a significant departure from the one thread per heddle method employed in plain weave. This research, based on the premise that such a warp



treatment may have been foundational to the 2/2 twill weave structure, focused on what appeared to be an obvious problem when using the heddle-rod supports as they survived in Norway, namely heddle jamming. The resulting method presents a solution that includes several attested aspects of the warp-weighted loom tradition: the use of two threads per heddle for weaving twill, as reported from Iceland; the use of double-notched supports as documented from medieval finds in Trondheim; and the use of single-notched heddle-rod supports based on those in surviving Norwegian weaving traditions. The blending of these factors to devise a method for weaving twill stands in contrast to the basis for the four-weight-row method: a new device envisioned to facilitate a novel approach.

It seems likely that over time a variety of methods were employed to weave twill on the warp-weighted loom, perhaps including all of those described in this article. This was, after all, an important fabric and weavers are endlessly inventive. Those using a loom similar to the one that survived in Norway may well have worked with an imperfect system, clearing heddle jams and occasional tangles while using one, two or three pairs of supports, until a solution such as the double-notched supports presented itself. It is possible that some weavers experimented with loom refinements that allowed more flexibility in what fabrics could be woven, and if so, they may have come upon the idea of using double-notched supports in a four-weight-row system, just as Haynes did. But given the problems inherent with that system, such a method was probably never widespread.

Without a living tradition to provide evidence, the manner in which twill was woven on the warp-weighted loom remains open to conjecture. However, if double-notched supports were a part of that method, the use suggested by the current research seems the most likely.

### Acknowledgements

The authors would like to thank the Osterøy Museum, a division of the Museum Centre in Hordaland, Norway, for allowing experimentation on their warp-weighted looms.

### Bibliography

- Andersson Strand, E. (2010) The basics of textile tools and textile technology: from fibre to fabric. In M-L. Nosch and C. Michel (eds), *Textile Terminologies in the Ancient Near East and Mediterranean from the Third to the First Millennia BC*. Oxford: Oxbow Books, 10–22.
- Andersson Strand, E. (2015) The basics of textile tools and

textile technology – from fibre to fabric. In E. Andersson Strand and M-L. Nosch (eds), *Tools, Textiles and Contexts: Investigating Textile Production in the Aegean and Eastern Mediterranean Bronze Age*. Ancient Textiles Series 21. Oxford: Oxbow Books, 39–60.

- Andersson Strand, E. and Demant, I. (2023) *Fibre, Tools & Textiles: Fashioning the Viking Age 1*. Copenhagen: National Museum of Denmark.
- Batzer, A. and Dokkedal, L. (1991) Opstadvæven nye forsøgsobservationer. In B. Madsen (ed), *Eksperimentel Arkæologi, studier i teknologi og kultur nr. 1*. Lejre: Historisk-Arkæologisk Forsøgscenter.
- Batzer, A. and Dokkedal, L. (1992) The warp-weighted loom: some new experimental notes. In L. B. Jørgensen and E. Munksgaard (eds), *Tidens Tand. Archaeological Textiles in Northern Europe, NESAT IV*. Copenhagen: Konservatorskolen, Det Kongelige Danske Kunstakademi, 231–234.
- Broholm, H. C. and Hald, M. (1935) *Danske Bronzealders Dragter*. Nordiske Fortidsminder II (5–6). Copenhagen: Det Kongelige Nordiske Oldskriftselskab.
- Crowfoot, G., Pritchard, F. and Staniland, K. (1992) *Textiles and Clothing c. 1150–1450*. London: HMSO.
- Emery, I. (1966) *The Primary Structures of Fabrics, An Illustrated Classification*. Washington: Textile Museum.
- Grömer, K. (2016) *The Art of Prehistoric Textile Making: The Development of Craft Traditions and Clothing in Central Europe*. Vienna: Natural History Museum Vienna.
- Guðjónsson, E. E. (1985) *Nogle bemærkninger om den islandske vægtvæv, vefstaður*. By og Bygd Årbok 1983–84. Oslo: Norsk Folkemuseum, 116–128.
- Hákonardóttir, H., Johnston, E. and Kløve Juuhl, M. (2016) *The Warp-Weighted Loom, Kljásteinavefstaðurrinn, Oppstadveven*. Leikanger: Skald Forlag.
- Hansen, E. H. (1978) *Opstadvæv, Før og Nu*. Copenhagen: Teamco.
- Haynes, A. E. (1975) Twill weaving on the warp-weighted loom. *Textile history* 6, 156–164.
- Hoffmann, M. (1964) *The Warp-Weighted Loom: Studies in the History and Technology of an Ancient Implement*. Studia Norvegica 14. Oslo: The Norwegian Research Council for Science and the Humanities. Reprint 1974, Oslo: Robin and Russ Handweavers.
- Hoffmann, M. (1952–1953). *Oppstadveven: Veveforsøk på Norsk Folkemuseum*. Unpublished research, Norsk folkemuseum archives.
- Nordeide, S. W. (1994) Håndverket. In A. Christophersen and S. W. Nordeide (eds), *Kaupangen ved Nidelva*. Trondheim: Riksantikvarens Skrifter 7, 213–241.
- Nørgård, A. and Østergård, E. (1994) A reconstruction of a blanket from the Migration Period. *Archaeological Textiles Newsletter* 18/19, 17–19.
- Olavius, O. (1780) *Oeconomisk Reise igiennem de nordvestlige*,



- nordlige og nordostlige Kanter af Island*. Copenhagen.
- Olofsson, L. and Nosch, M-L. (2015) Test of loom weights and 2/2 twill weaving. In E. Andersson Strand and M-L. Nosch (eds), *Tools, Textiles and Contexts: Investigating Textile Production in the Aegean and Eastern Mediterranean Bronze Age*. Ancient Textiles Series 21. Oxford: Oxbow Books, 119–126.
- Øye, I. (2016) When did weaving become a male profession? *Danish Journal of Archaeology* 5 (1–2), 34–51.
- Schierer, I. (2005) Experiments with the warp-weighted loom of Gars-Thunau, Austria. In P. Bichler, K. Grömer, R. H. Deijzer, A. Kern and H. Reschreiter (eds), *Hallstatt Textiles: Technical Analysis, Scientific Investigation and Experiment on Iron Age Textiles*. Oxford: Archaeopress, 101–105.
- Schlabow, K. (1952) Der Prachtmantel No. II aus dem Vehnemoor in Oldenburg. In: H. Lübbling (ed), *Oldenburger Jahrbuch des Oldenburger Landesvereins für Geschichte, Natur- und Heimatkunde*. Oldenburg: Ad. Littmann, 160–201.
- Schlabow, K. (1976) *Textilfunde der Eisenzeit in Norddeutschland*. Neumünster: K. Wachholtz.
- Stærmoose Nielsen, K-H. (1999) *Kirkes væv, Opstadvævens historie og nutigide brug*. Forsøg med fortiden 6. Lejre: Historisk-Arkæologisk Forsøgscenter.
- Þórðarson, M. (1914) Ýmislegt um gamla vefstaðinn. *Árbók Hins íslenska fornleifafélags*, 3–26.
- Ulanowska, A. (2017) Innovative or traditional? Diachronic approach to weaving technology in Bronze Age Greece. *Światowit* 56, 57–73.
- Walton Rogers, P. (2007) *Cloth and Clothing in Early Anglo-Saxon England, AD 450-700*. Research Report 145. York: Council for British Archaeology.

Corresponding author:  
kllarson@uw.edu