



Handicraft Knowledge Applied to Archaeological Textiles

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Introduction Professor Lise Bender Jørgensen The Swedish School of Textiles, THS

Craftsmanship and know-how is an integral part of any textiles. This certainly applies to archaeological textiles, and experimental work on spinning and weaving is an important aspect of research done in this field. In this, two major problems have been recurrent. Firstly, how to assess the craftsmanship of extinct technologies, like hand spindles and the variety of looms that preceded the horizontal treadle loom. Secondly, how to *describe* craftsmanship, i.e. to transmit so-called tacit knowledge into an academic format. Hand-weaver Lena Hammarlund is engaged in finding ways towards solving both these problems, by producing test weaves, trying out a range of yarns, weaves and other variables, and by creating concepts and models to describe what she is doing. Hammarlund became interested in the study of ancient textiles during her sojourn at the University College Borås, The Swedish School of Textiles, and did her exam project on reconstructions of two Roman fabrics excavated at Mons Claudianus in Egypt (Hammarlund 1994). This led to an attempt to define what was termed the fourth dimension of the Mons Claudianus textiles (Hammarlund 1997, 1998), and to a series of related projects such as Textiles of Seafaring on the reconstruction of wool sails and other textiles for Viking ships (Bender Jørgensen & Damgaard Sørensen 1999; Cooke, Christiansen & Hammarlund 2002; Bender Jørgensen 2005; Cooke & Christiansen 2005). Hammarlund's contribution to this was based on studies of medieval textiles from Trondheim and Lödöse. This paper summarizes some of Hammarlund's main results.



Lena Hammarlund is educated in handweaving at The Swedish School of Textiles, THS, University Colleges of Borås. She has worked around 10 years with different project in archaeological and historical textiles.

Mons Claudianus

First a few words to introduce Mons Claudianus. A Roman quarry in Egypt's Eastern Desert, Mons Claudianus is situated between the modern Egyptian towns of Hurghada and Qena, approximately 50 km from the Red Sea and 120 km from the Nile. Excavations by an international team of scholars 1987-93 revealed rich finds, including textiles that are counted in tens of thousands (Bender Jørgensen 1991 b, 2000, 2004 a, b; Peacock & Maxfield 1997; Maxfield & Peacock 2001). Textual evidence shows that activities at the quarry can be dated mainly to the first half of the 2nd century AD, informs us on daily life at the site, and on the social and ethnic composition of the workforce (Bingen et al. 1992, 1997; Bülow-Jacobsen 1996; Cuvigny 2000).

Studying Textile Craftsmanship

The hand-weaver's primary role has been to find answers to specific questions, often concerning textile properties. One of the main questions concerning the wool tabby textiles from Mons Claudianus was why fragments with the same technical registration look so different from one another. To answer this, the textiles' surface texture has been studied, in an attempt to investigate the parameters that created different appearances (Hammarlund 1997).

Visual Groups and the Pentagon

A first impression from the wealth of Mons Claudianus textiles was that many of them could be sorted visually into distinctive types. Some were thin and sheer, and very lightweight, while others were thin but with more substance. Some were of medium thickness and others rather coarse. When, however, examined according to the standard methodology of the textile archaeologist (cf. Walton & Eastwood 1988), many of the textiles resulted in almost identical descriptions. Differences clearly visible to the naked eye were not discernible through the standard analysis of archaeological textiles. They contained a fourth dimension that eluded the established recording system.

This fourth dimension is concealed within the textile, imparted by the craftsperson or persons through their handicraft

knowledge and skills during all steps in the making of the fabric, from raw material to the finished cloth. How can these elusive aspects be described? To answer that question we have to know more about how these textiles have been made and how different processes affect a fabric. What factors from the construction processes, besides those used in standard analyses, are important to record?

The first step in the investigation was to weave a series of test webs to rule out the effects of simple technical variations, such as combinations of twist directions, and combinations of twist and different thread density. This work was followed by a study of detailed photos of 50 fragments from Mons Claudianus, where the aim was to find words to describe what characterised the fabrics' textures purely from a visual point of view.

Subjective Description

Following test webs and photographic analysis, fieldwork examination of more than 100 woollen tabby fragments took place. Tabby is the simplest weave and as such, it is, so to speak, an uncomplicated cloth. In spite of this fact, the tabby textiles contained a broad variation of fabrics. In this part of the study, the textile archaeologist's analysis was supplemented by that of the craftsman's. This resulted in a two-part analysis, with a technical and a subjective description. The technical analysis was based on standard methods (Walton & Eastwood, 1988), supplemented by yarn diameter, twist, and thread movement (i.e. sideways movement of thread or movement caused by thread contraction; see below). The subjective description was based on visual impression and assessment of the fabric. It included data such as:

- *Fibre character*: finer or coarser, pigmented or non-pigmented
- An estimation of *fabric thickness and density*
- *Fabric character*: 'ordinary', 'extraordinary' or 'special' in some way, with an explanation of what factors this assessment is based on
- *Time and skill invested in the work*, e.g. spinning, weaving, with an explanation of what factors this assessment is based on

- *Surface texture*: the visual characteristics of the fabric's surface
- *Feeling*: a description of properties that may suggest the fabric's use. The word 'feeling' is used on archaeological textiles where the modern textile industry would employ the term 'handle'.

It is important to extract as much information as possible during primary recording, because it became apparent then, that in earlier work with photographs and other two-dimensional documentation, these secondary recording methods did not satisfactorily convey aspects of the textiles that were necessary for subjective recording, as listed above. However, the resulting subjective description from primary recording is of great importance and help when later interpreting technical data and analysing photographic material.

Of the analysed fragments, 92 were selected for grouping according to visual similarities. They all were made of wool, probably fabrics for clothing, and at first glance they looked to be woven in tabby. When analysed, it was discovered that a few were woven in basket or half basket weaves but their visual appearance was that of tabby.

Visual Description of Tabby Groups

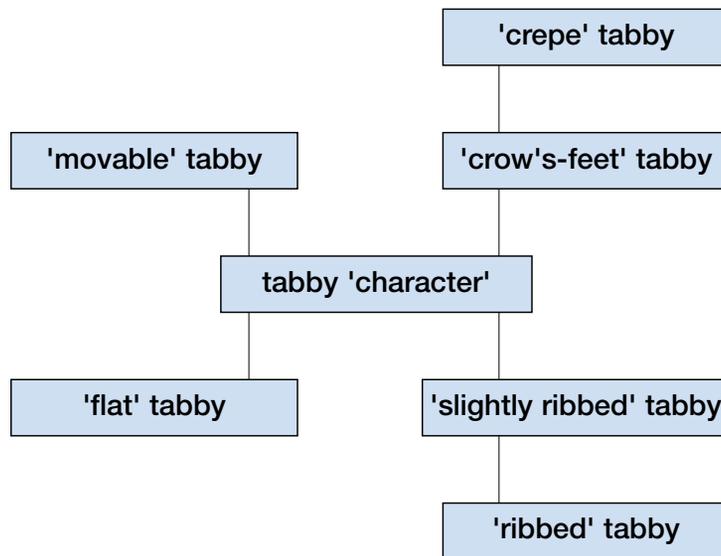
The 92 fragments resulted in seven different visual groupings, with their characteristics listed below. During examination of each group it was important to put into specific words the visual characteristics common to the group. Some fragments were easily assigned to a specific group; other textiles were more difficult to ascribe to one group, since their characteristics varied by degree, and could be common to more than one group.

On the basis of the characteristics of each group it has been possible to construct a model, describing the relationships among the visual groups.

In the model, **tabby 'character'** is placed in the centre. The characteristics of the three groups at the top of the model are that warp and/or weft yarns have some sort of movement and that the warp is not so spaced and the weft is not so densely packed as in the three groups at the bottom of the model. Fabrics in the three groups at the bottom are mainly characterised by warp and weft yarns that have no movement, and thread systems that appear straight; these fabrics are densely woven but with a more open spaced warp and a tight, or very tightly packed, weft.

These groupings, based on the visual appearance of the textile, are the starting point in finding a key that will explain why a textile displays its particular appearance. What is it that determines that a fragment woven in tabby will correspond to a specific group or category?

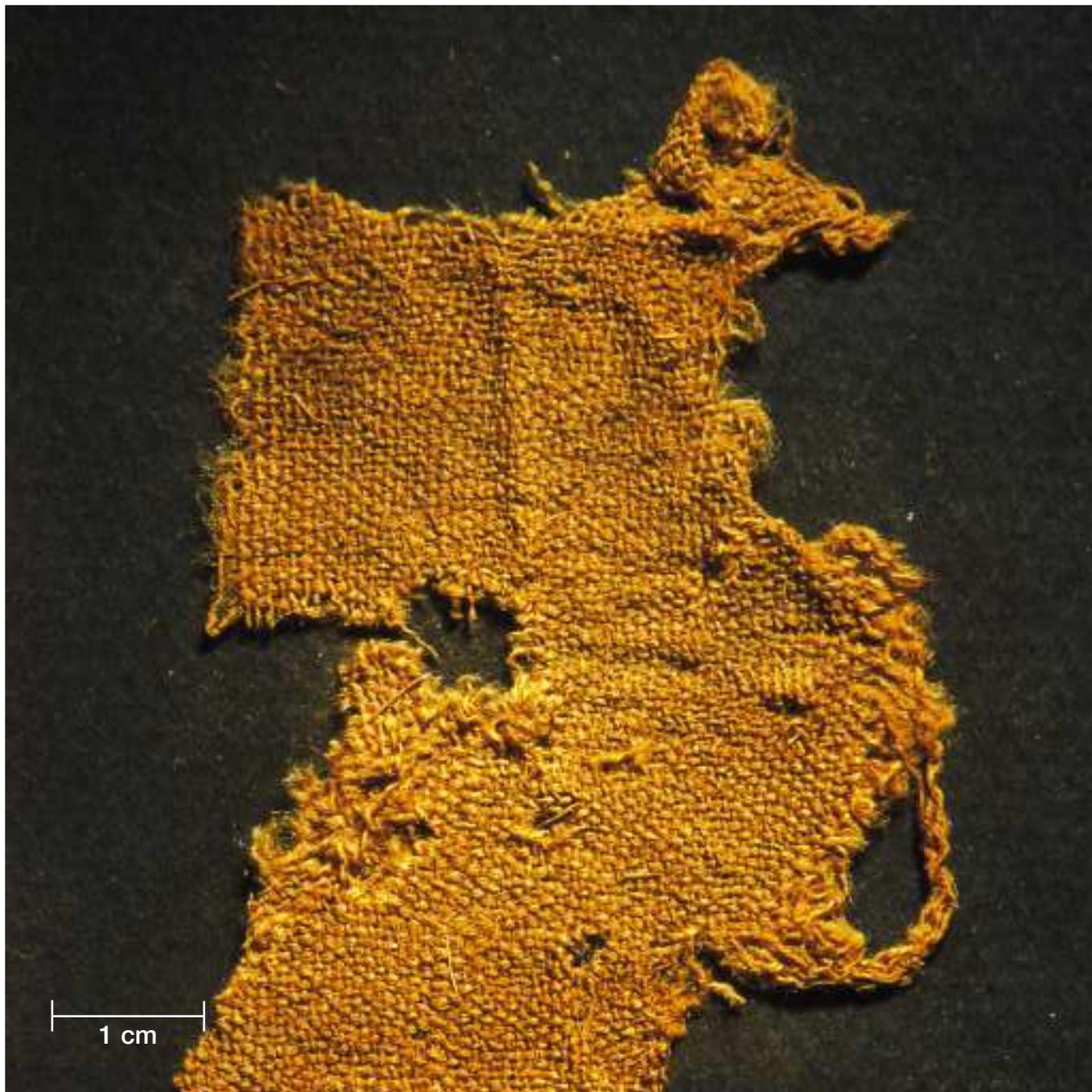
Relationships between visual tabby groups



tabby 'character'

Appears as a distinct tabby weave, looking balanced, and with thread systems that appear straight.

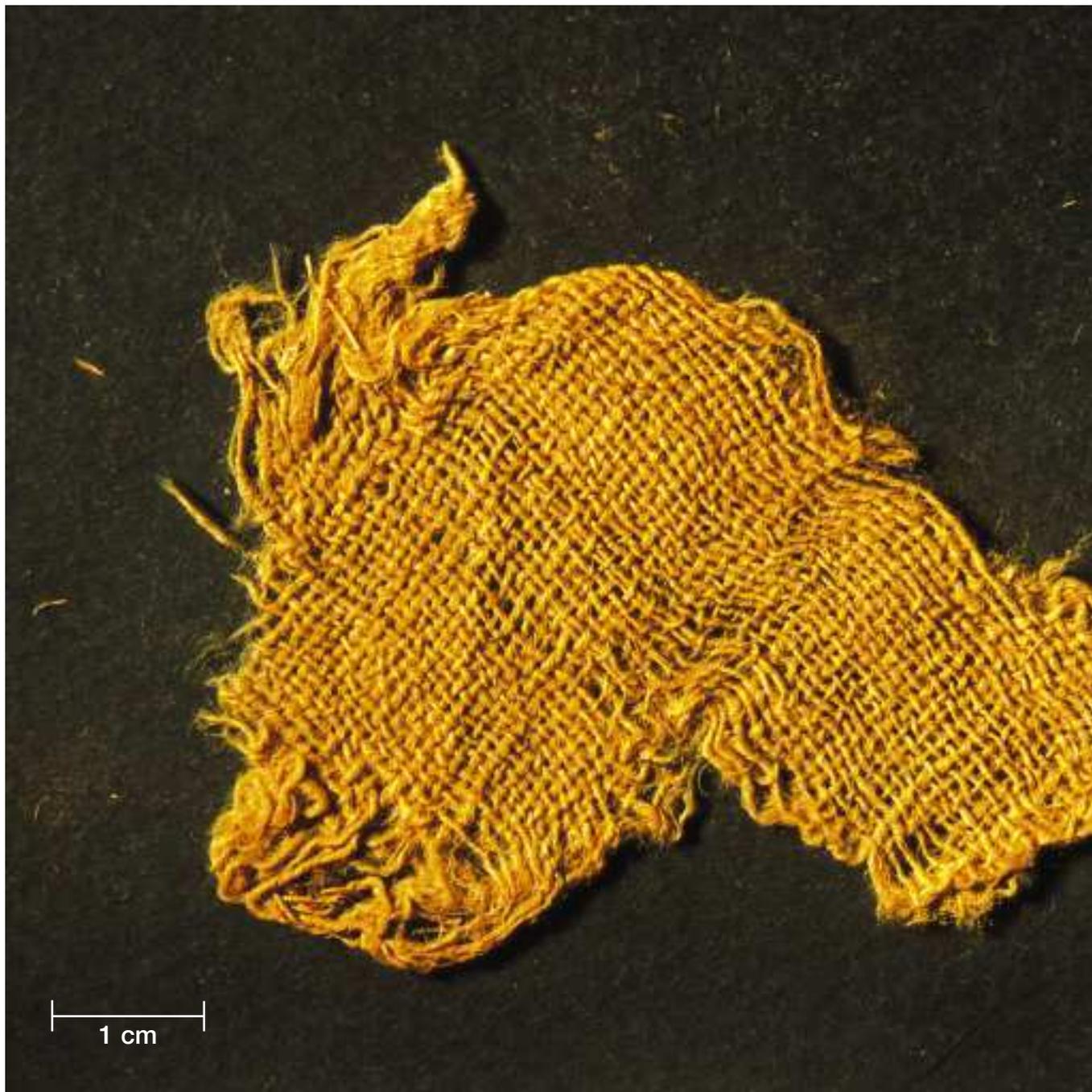
MC 0133



1 cm

'movable' tabby

Has a curving or undulating movement in the yarn in one or both thread systems and this movement is seen as two-dimensional. There is a noticeable space between the threads.
MC 0150

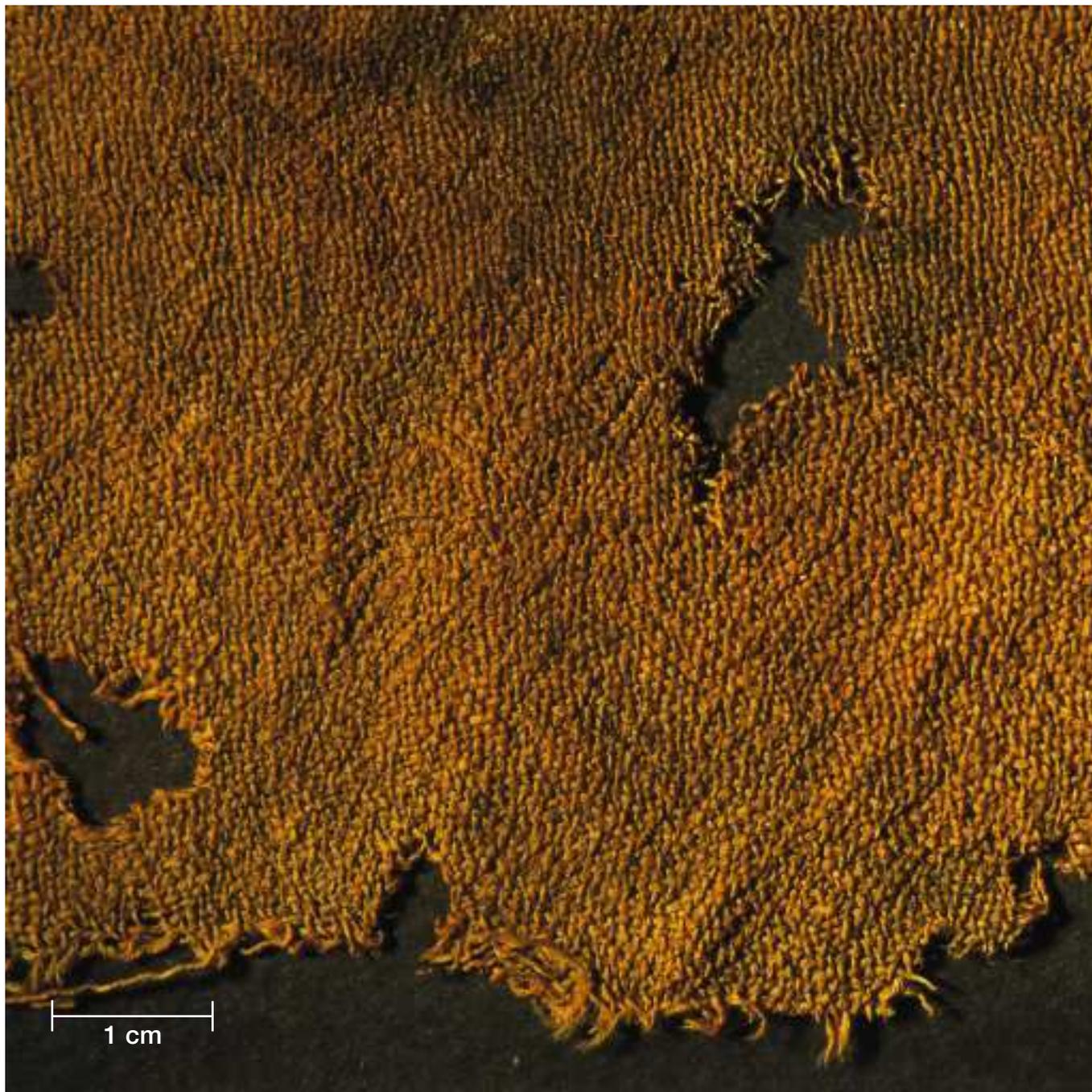


1 cm

'crow's-feet' tabby

Is characterised by lines on the fabric surface that resemble a bird's footprint. These lines can be created both by the warp and weft yarns, forming a faint twill or diamond pattern. The lines occur due to movement in the yarn; twist determines how clearly the lines are visible. This phenomenon is seen as a three-dimensional movement.

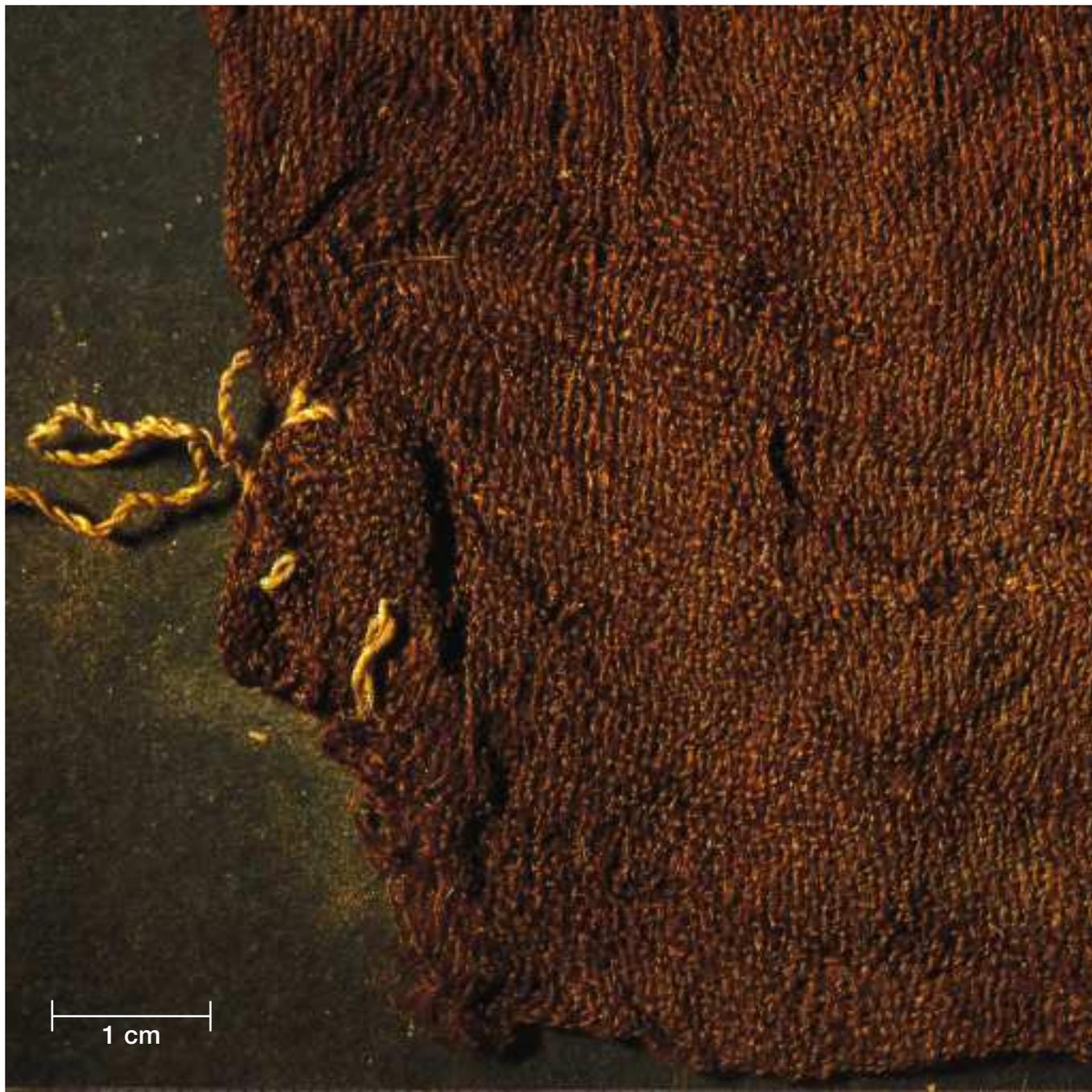
MC 0070



'crepe' tabby

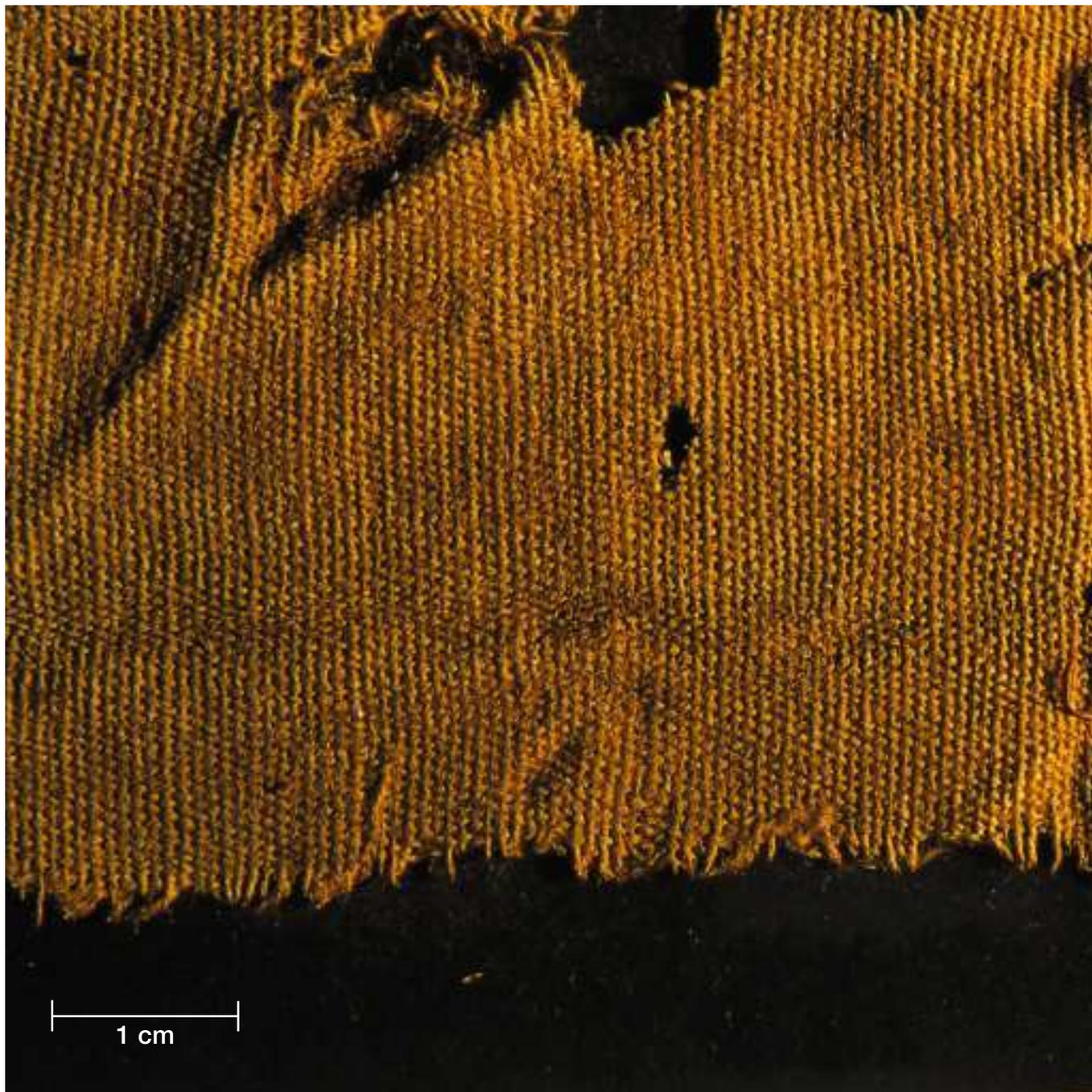
Has a more or less bubbly surface, with thread movement that is seen as three-dimensional. Both open weave and dense textiles can be found in this group.

MC 0579



'flat' tabby

Is seen as a fabric with a very smooth, flat surface where the binding texture is more or less invisible. They have often a weft-faced appearance, and seem to have straight thread systems. The weft yarn is loosely spun which allows it to 'spread out'. They have a fine warp and weft, which makes them very thin or thin fabrics. If coarser, the textile no longer looks smooth and flat because the yarns' contours will dominate and these textiles cannot be grouped as "flat tabby".
MC 0002



'slightly ribbed' tabby

Is a fabric with faint ribs in the warp direction. It is weft-faced, with straight thread systems. The group includes thin as well as slightly coarser fabrics. The weft yarn is usually, but not always, loosely spun.

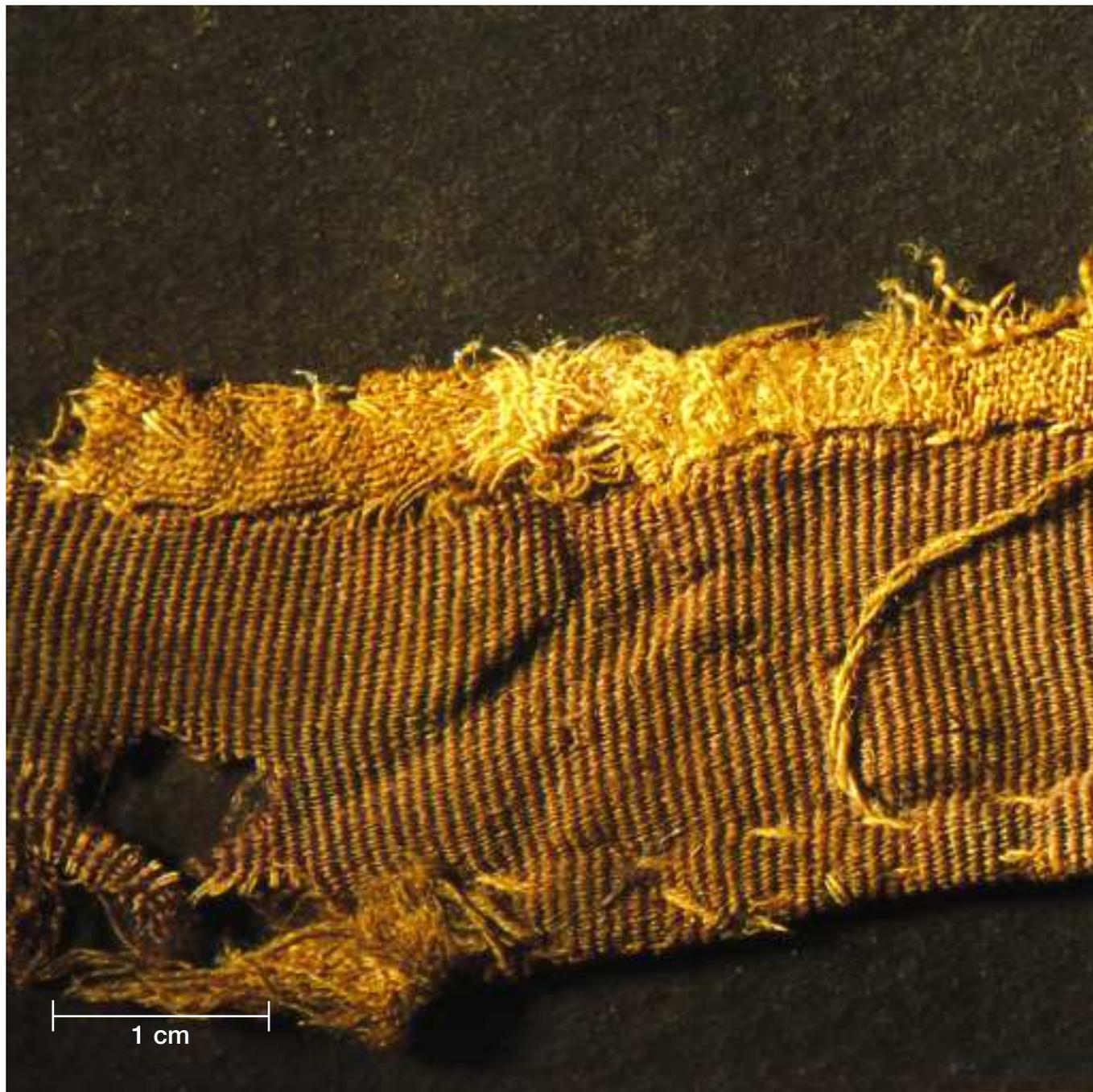
MC 0742



'ribbed' tabby

Has distinct ribs in the warp direction and straight thread systems. The warp is well spaced and the weft very densely packed. The weft yarn usually is finer than the warp and often, but not always, loosely spun. Only one in five textiles listed in this category is tabby; most are woven in half-basket or basket weave.

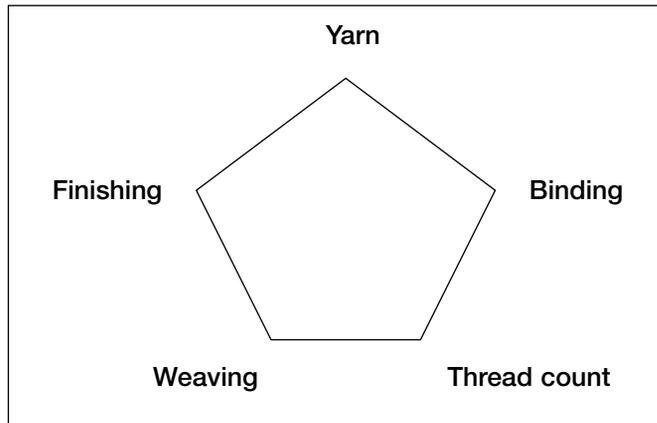
MC 0741



The Pentagon

An initial attempt to answer this question was to examine the similarities of the textiles placed in the same category, by using a combination of traditional analysis and the subjective description. The result was not very informative: only very general tendencies could be established. The reasons for this can be many: too few textiles in the sample, imprecise measuring methods, or incomplete knowledge about fibre qualities and weaving methods, tools, and finishing methods and how they affect the textile. Instead, it was necessary to establish an interpretation based on theoretical and practical knowledge of handicraft, as well as information from traditional analytical methods and subjective description.

In hand weaving, one learns that a fabric's type or quality is determined by **yarn**, **thread count**, and **binding** or weave. When describing the textiles from Mons Claudianus, this was not enough. Something more could be seen in the fabrics than what could be explained by those factors. During the project, test weaving was done on different early loom types. The test weaves on these looms showed differences in texture, in comparison with test pieces woven on the horizontal treadle loom. Different types of finishing methods also were tested and showed very clearly how they affected the fabric. As a result, two more factors were added: **weaving**, which encompasses loom type, tools for weaving, and how the weaver works; and various final fabric processes under the heading, **finishing**.



The Pentagon

The pentagon model is a simple way to illustrate the handicraft factors that form the foundation of a fabric's appearance and properties. To understand the complexity and interaction of these factors, their definitions first are explained.

Yarn: a continuous strand, single or compound, made from any fibre or filament by reeling, spinning, twisting, or throwing (Burnham 1981). Yarn properties can be divided into two groups:

- Those that originate from the fibre itself, such as length, fineness or fibre diameter, crimp, absorbency, and abrasion resistance (Boutrup 1996; Collier & Tortora 2001; Hantverkets bok 1940).
- Properties that originate from the spinning process, such as twist, twist direction, how the fibres are orientated in the yarn, and yarn diameter (Boutrup 1996; Collier & Tortora 2001; Hantverkets bok 1940).

Binding or Weave: the system of interlacing threads of warp and weft according to defined rules in order to produce all or parts of a textile (Burnham 1981). In the first part of the Mons Claudianus project, the examined textiles primarily were tabby, the simplest binding. Tabby is a basic binding methods based on a unit of two warp threads and two weft threads, in which each warp thread, alternately, passes over one and under one weft thread (Burnham 1981).

Thread count: the number of threads in warp and weft per unit of measure (Burnham 1981).

Weaving: the effect of the interplay between the loom, the weaving tools, and how the weaver works. Looms in use during the Roman period were most probably the horizontal ground loom, the vertical two-beam loom, and the warp-weighted loom (Barber 1991; Broudy 1979; Geijer 1980). Different looms require different types of secondary tools, and weaving is performed in different ways. This can affect a textile's appearance, and at times, may be discernible.

Finishing: finishing processes are performed on the web when taken off the loom. Finishing can include wetting, stretching, application of dye, fulling the fabric, or a combination of these processes. When dealing with archaeological textiles it can be difficult to ascertain what is the primary, deliberate textile finish and what has occurred through wear and tear, or as a result of deposition and degradation (Collier & Tortora 2001; Gohl & Vilensky 1983; Marsh 1947; Hantverkets bok 1940).

Two other important variables may determine to which visual group a textile will belong: **variability in thread spacing** and **thread movement**. These variables are each the result of the interplay of several factors within the Pentagon and therefore, are not included in the five basic factors of the model.

Variability in thread spacing: fabrics produced on looms without a reed and batten can show a marked variability in the spacing of warp and weft threads, due to the fact that they are not subjected to strict spacing and parallelism obtained by such looms. Looms without a reed allow warp threads some room for sideways movement, depending on thread density (Cooke et al 2002). Variability in spacing of the weft can depend on how densely the weft is packed and how the beating method and choice of beating tool (sword, comb, etc.) influences the thread systems. Variability in spacing is primarily assigned to **weaving** in the Pentagon model but fabric density, a combination of yarn diameter, thread count, and binding, can also affect it.

Movement in one or both thread systems is caused by a combination of torsion, friction, and the fabric's density.

a) Torsion is caused by the fibres' resistance to being twisted, and works counter to the spin direction. Its strength primarily depends on degree of twist in the yarn but also the fibre type and fibre diameter.

b) Friction relates to the resistance created where yarn surfaces touch; it depends on yarn factors such as fibre type, fibre preparation, and degree of twist.

c) The fabric's density determines to what extent torsion and friction can act, and what type of surface expression the fabric will show.

Movement can be perceived as either two or three-dimensional in nature. Primarily it is assigned to **yarn** in the Pentagon but fabric density can also affect it.

Applying the Pentagon: re-examining the visual groups

To obtain a clearer image of how the textiles in the visual groups were constructed, it was necessary to apply theoretical and practical knowledge of craftsmanship and skill. For this purpose, the Pentagon model described above was used along with the concepts of variability in thread spacing and movement.

Each textile fragment was reassessed in light of the craftsman's knowledge of what happens in a fabric during its construction. New details were added to the descriptions of the seven visual groups.

- **tabby 'character'** (page 95) appears as a distinct tabby weave, looking balanced, and with thread systems that appear straight. The balanced look is due to the thread-count in conjunction with yarn diameter. The straight thread systems arise from a dense sett, which does not leave sufficient space between threads to allow movement. This may be the result of construction on the loom and the weaving, or that the fabric has been through a finishing process that prevents movement and thereby keeps the threads straight.

- **'movable' tabby** (page 97) has a curving or undulating movement in the yarn in one or both thread systems and this movement is seen as two-dimensional. There is noticeable space between the threads. Twist in the yarn, combined with sufficient spacing between threads, allows for movement. Here, torsion has a mutual relationship with thread count and/or yarn diameter that may create this type of movement, but hinders the development of 'crow's-feet' or 'crepe' tabby. To allow movement to take place, there also must be enough space between the threads. This space can be due to a more open sett, but space also can occur due to the variability in thread spacing caused by weaving. It is unlikely that the textile has been through a hard finishing process, since shrinking would be likely to occur and impede this type of movement.
- **'crow's-feet' tabby** (page 99) is characterised by lines on the fabric surface that resemble a bird's footprint. The lines are created by warp and/or weft yarns forming a faint twill or diamond pattern. This phenomenon is seen as a three-dimensional movement. Lines occur when the threads are relatively well balanced both in thread count and diameter. Some space between the threads also is necessary, but not as much as in 'movable' tabby. The lines are caused by a combination of torsion in the yarn and the fact that spacing and yarn diameter allow movement. Twist determines how clearly the lines are visible. When a yarn attempts to untwist, tension occurs and the yarn will form small, local elevations on the fabric's surface. In 'crow's-feet' tabby, these appear with regularity and form diagonal lines. It is important to note that twist direction does not influence this phenomenon. The fabric has not been through a hard finishing process.
- **'crepe' tabby** (page 101) has a more or less bubbly surface with thread movement that is seen as three-dimensional. Both open weave and dense textiles can be found in this group. They combine hard to very hard twisted yarns in at least one system with open spacing, or very hard twisted yarns in one or both systems with higher thread density. If thread count and/or yarn diameter is balanced, the textiles differ from 'crow's-feet' tabby in having a more dense sett and/or a higher yarn torsion, which creates a bubbly appearance instead of lines. If thread count is unbalanced, with dense warp sett and more spaced weft, or vice versa, the small, local elevations that in 'crow's-feet' tabby create lines, become, in 'crepe' tabby, so steep or flattened that the eye does not perceive them as diagonal lines at all. Instead, they merge with the warp or weft. Some 'crepe' tabbies have a torsion that is so high that the bubbles appear to cover the surface totally. A crepe look can appear in all twist combinations, s/s s/z, z/z, z/s, but they give various textures to the fabric. The denser fabrics in this group have probably been through a hard finishing process.
- **'flat' tabby** (page 103) is seen as a fabric with a very smooth, flat surface, where the binding texture is more or less invisible. They often have a weft-faced appearance, and have straight thread systems. The weft yarn is loosely spun which allows it to 'spread out'. They have a fine warp and weft, which gives very thin or thin fabrics. If coarser, the textile no longer looks smooth and flat because the yarns' contours will dominate and these textiles cannot be grouped as 'flat' tabby. The more or less weft-faced sett, in combination with the fine yarns in both systems and the loosely spun weft, create this very smooth, flat surface. The relatively high thread density, in combination with the loosely spun weft yarn that tends to 'spread', leaves no room for movement. This also causes the thread systems to appear straight, even if the warp is not exactly evenly spaced. The fabric probably has been through a relatively hard finishing process.
- **'slightly ribbed'** (page 105) tabby is a fabric with faint ribs in the warp direction. It is weft-faced, with straight thread systems. The group includes thin as well as slightly coarser fabrics. The weft yarn is usually, but not always, loosely spun. The faint ribs are due to a slightly

coarser or a more spaced warp than in 'flat' tabby and they have such a dense weft that no movement is allowed. The thread systems appear straight due to weft density and possibly also because the fabric has been through a hard finishing process, which may straighten irregularities.

- **'ribbed' tabby** (page 107) has distinct ribs in the warp direction and straight thread systems. The warp is well spaced and the weft is very densely packed. The weft yarn usually is finer than the warp and often, but not always, loosely spun. The distinct ribs are created by a wellspaced warp that is clearly coarser than the weft, together with very high weft density. The high density prevents movement. As in 'slightly ribbed' tabby the thread systems appear straight due to the weft density and probably also a finishing process that may straighten irregularities. It is most likely that these fabrics have been through a hard finishing process.

Using traditional technical analyses, the Mons Claudianus tabby textiles appeared to be a relatively homogenous group. Visually, however, there were clear differences, and through a more comprehensive technical analysis, together with subjective analysis and using handicraft knowledge, it was possible to understand and explain these differences.

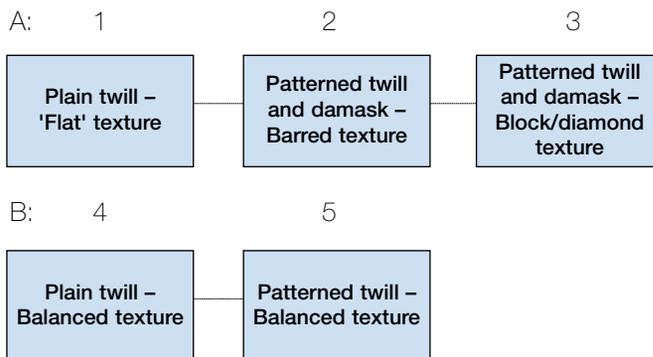
Visual Groups: Twill and Damask

The approach of visual grouping was also applied to the woolen twills and damasks from Mons Claudianus. At an early stage the damask textiles were also included, as they proved hard to separate from twills by the eye. Five easily assigned visual groups were established. They include most of the analysed textiles: 1; thinner, plain twills, with a flat texture, connected, in some way, to 2; thinner twills and damasks with a slightly barred texture and to 3; thinner twills and damasks with a block or diamond patterned texture.

Also 4; coarser, plain twills, with a balanced texture connected to 5; with a balanced texture somewhat a little thinner than group 4, with a block or diamond patterned texture, including a few textiles in broken-reverse twill.

Further, these groups can be divided into two different categories, A: the first three groups being thinner and more or less weft-faced and B: the last two groups, being often coarser and balanced.

The following model illustrates the relationship between the established groups.



Model of visual twills and damask groups

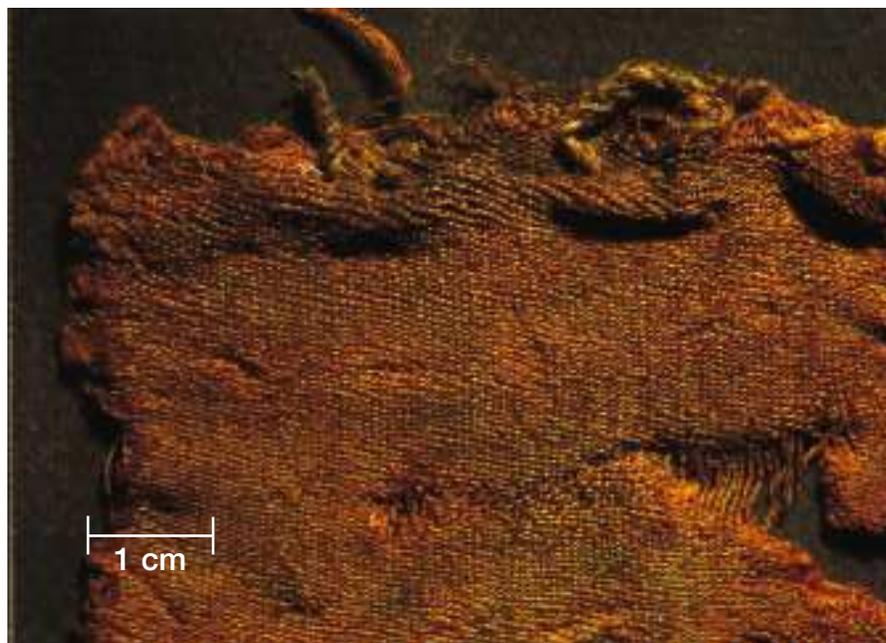
Description and characterisation of the visual groups

Plain, 'flat' twill

Contains thinner twills, so tightly woven that it is difficult to determine if the binding is 2/1 or 2/2 twill. They give a dense, stable expression without being stiff. Many are brown. The group shows affinity with the 'flat' tabby textiles. As in the 'flat' tabby group the weft yarn is loosely spun which allows it to 'spread out', and the more or less weft-faced sett, in combination with fine yarns in both systems and the loosely spun weft, create its smooth, flat surface. The high weft density, in combination with the loosely spun weft yarn, leaves little room for movement and causes the thread systems to appear straight, even if the warp is not exactly evenly spaced. The fabric probably has been through a relatively hard finishing process.

MC 1139: 2/1 twill

MC 1217: 2/2 twill

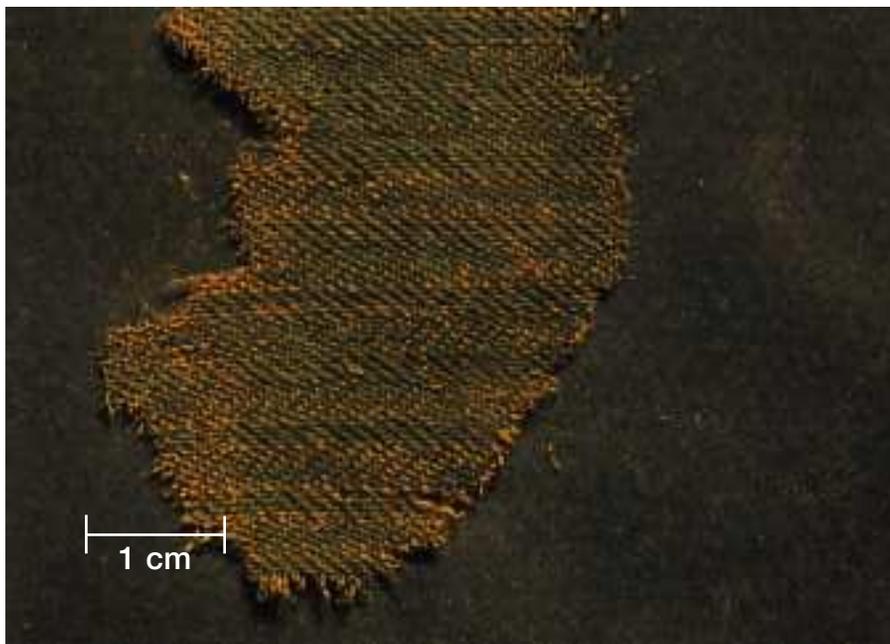
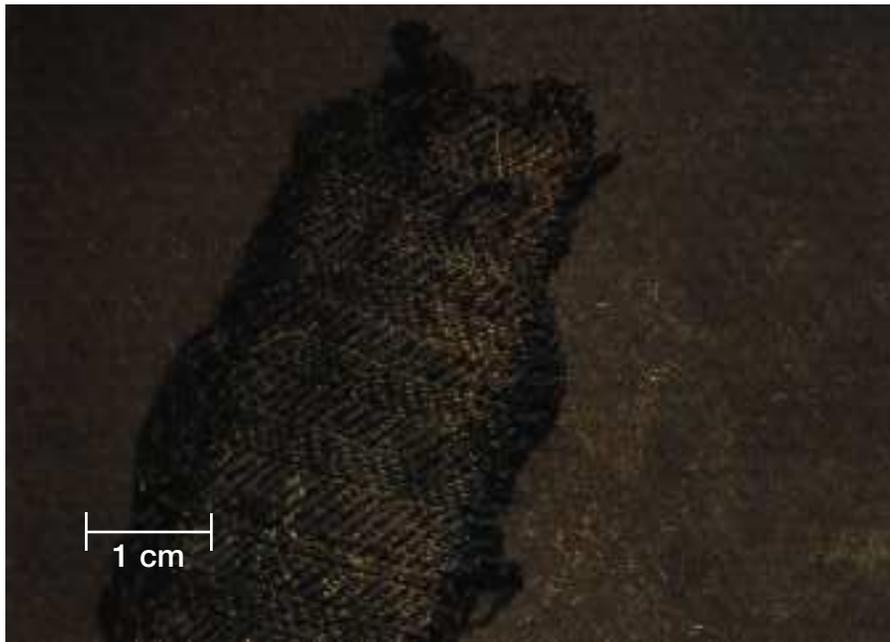


Barred patterned twill and damask

This group consists of barred damasks and a few broken-reverse twills. The fabrics are classified as thinner and give an expression of being densely woven, but they are not as dense as some of the 'flat' twills. Most of the textiles are dyed, mainly blue. As the 'flat' twills they give a stable expression without being stiff and have a smooth surface. Both the damask and the broken-reverse binding give the textiles a striped or barred texture in weft-direction, and this together with similarities in thickness, density and colour places the textiles in the same visual group.

MC 1098: broken reverse twill

MC 0745: barred damask

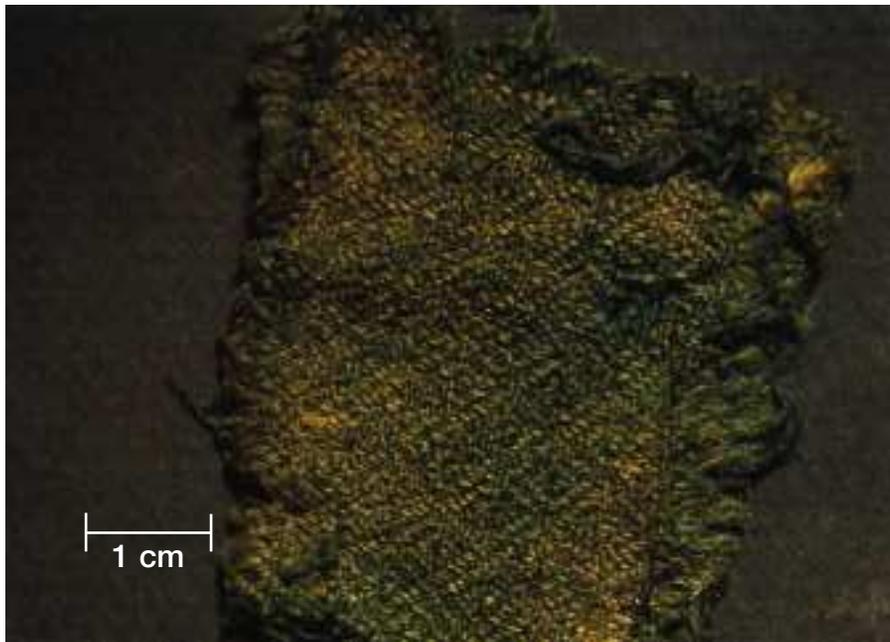
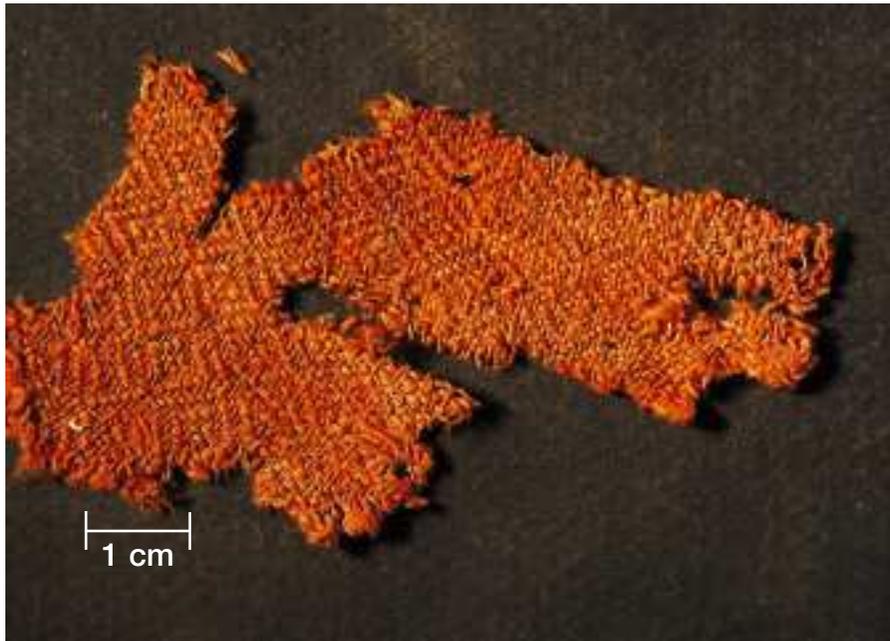


Block patterned twill and damask

This group also consists of damasks and a few diamond twills. The bindings give the textiles a block or sometimes a diamond pattern. These, too, are classified as thinner and with an expression of being dense, but they are in general not as dense as the two groups described above. They also give a more durable or pliable feeling with a more woolly surface texture than the two previous groups. This may probably be due to that fact that the fabrics are not so densely woven. The fabrics are generally dyed green or red. The both bindings give the textiles common pattern and this together with similarities in thickness, density and colour places the textiles in the same visual group (cf. Roman damasks see Ciszuk 2002).

MC 1088: diamond twill

MC 1097: block damask

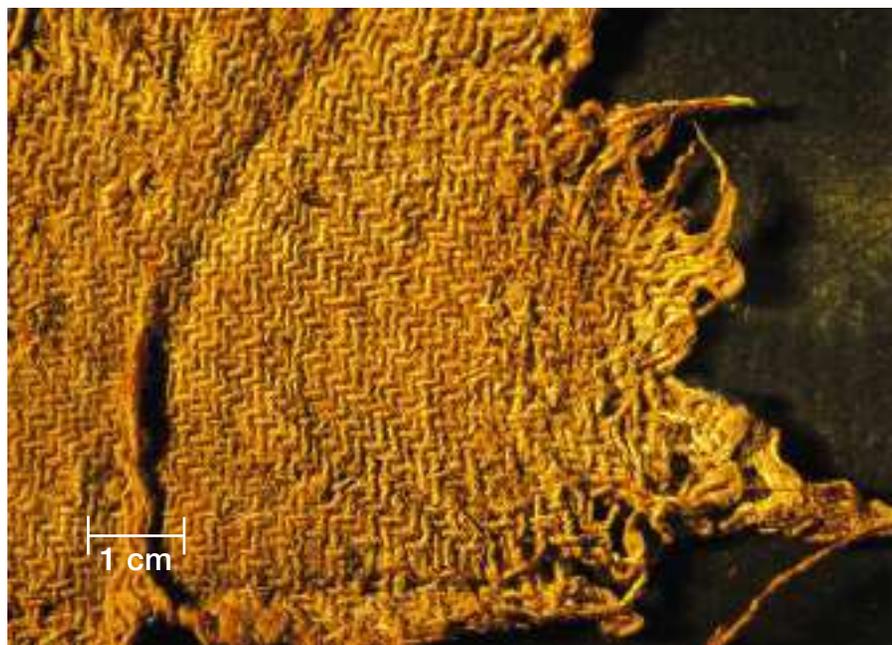


Plain, balanced twill

This group contains both 2/1 twills and 2/2 twills. Fabrics of this group appear distinctly different from the above types and also from the majority of tabbies. This is due to the well-balanced appearance in combination with the fact that it is, in most cases, not possible to distinguish between warp and weft yarns and that the textiles are coarse. The balanced look is due to the threadcount in conjunction with yarn diameter and this gives the textiles a distinct twill character. Dyed textiles are not so common.

MC 0531: 2/1 twill

MC 1132: 2/2 twill



Patterned, balanced twill

In this group the majority of the textiles are diamond twills. Only a few are woven in broken-reverse twill, and some of them are so small that they may have been diamond twills. The textiles are thinner than the group above but give the same impression of being well balanced. It is striking that the pattern unit is of so similar size. Many of the textiles are dyed. This group is closely related to the balanced plain twills, the visual difference lays only in thickness and pattern. MC 1378: broken reverse twill
MC 1068: diamond twill



Normally, textiles are grouped according to technical aspects such as binding and twist- directions. The visual groups outlined above do not fit into this structuring principle. Instead, aspects such as expression of density, balance, and patterning are decisive and these capture the fabrics' character.

Fabric Thickness and Density: a method of grouping textiles

One of the aims of the Textiles of Seafaring project was to identify textiles that were suitable for use as sails, or garments appropriate for use at sea among medieval textiles from Trondheim and Lödöse. Properties such as warmth, wind- and water resistance, and strength were investigated, and related to relevant parameters in the fabrics' structure. It became clear that fabric thickness and density were important factors in understanding and comparing textile texture and structure, for sailcloth as well as fabrics for garments. This, combined with knowledge built up during work with Mons Claudianus textiles, resulted in an attempt to capture and classify fabric thickness and density.

Fabric Thickness and Density

The textile industry uses weight per square unit to classify textiles into different qualities, such as light or heavy weight fabrics. Thickness also can be measured by compressing the fabric with a specific pressure between two solid, parallel plates. The interval between the plates gives the fabric's thickness. Neither method is easily applied to archaeological textiles.

To describe fabric density the textile industry uses cover factor (Russell 1965). The definition of cover factor is the ratio of the area covered by the yarn, to the total area covered by the fabric (Wynne 1997; Collier & Tortora 2001).

The cover factor is calculated by the following formula:

$$WA + WE - (WA \times WE)$$

where WA and WE stand for thread count per cm x yarn diameter (cm) in the warp and weft respectively. This formula produces a number which represents the fabric's density; the higher the number, the more dense is the fabric. The theoretical maximum density is 1.0 and therefore, a measure of 0.9 represents a dense fabric (Kärman 1996; Russell 1965). This calculating formula can be used on archaeological textiles.

Fabric Thickness in Archaeological Textiles

To find a way to describe and quantify thickness in archaeological textiles was complicated, since methods used by the textile industry were not applicable. A method used by archaeologists to describe or group textiles is to use the fabric's thread count, or the number of threads per cm in warp and weft. In this method a low thread count corresponds to a coarse quality textile and conversely, a high thread count reflects a fine quality fabric (Tidow 1982; Bender Jørgensen 1991 a). However, thread count is a quantitative measure and thus it can be misleading to use it as a qualitative description such as coarse, medium or fine, without taking into account the diameter of the threads.

Instead, a system based on comparisons of visually perceived thickness, noted when analysing textiles was developed. The Lödöse textiles offered an opportunity to apply a very careful comparison. The room where the analysis took place made it possible to display all of the textiles at once, thereby allowing to sort them into groups by thickness. The visually perceived fabrics' densities and how that influenced perception of thickness was also noted. Research on the Trondheim and Lödöse material resulted in six different thickness groups based on visual observations and this gave a good basis for further work.

The next step in finding a way to classify a fabric's thickness was to develop a method based on quantifiable measures. This began with the Lödöse textiles because they comprised the collection that had received the most systematic examination. Subsequently, the textiles from Trondheim and Mons Claudianus were included, allowing a broader approach.

Theoretical studies in weaving, and experiences from practical work with both reconstruction and test weaving, show that yarn diameter is an important factor in a fabric's thickness. Therefore, it was decided to test if it was appropriate to use yarn diameter in warp and weft as a measure of a textile's thickness.

Yarn Diameter and Visually Perceived Thickness

In Diagram 1 the hypothesis - that yarn diameter in warp and weft is a measure of approximate thickness was tested. Each textile from the six visually perceived thickness groups from Lödöse has been added to the diagram according to its warp and weft yarn diameters.

Diagram 1 shows a correlation between yarn diameter and visual thickness group. There is some overlapping, although in these case notes from the original analysis were carefully reviewed. In some cases it showed that the textile was difficult to assess. For example, a medium-coarse textile with the same yarn diameter as a medium textile had a notation of 'medium-coarse towards medium'. For other textiles it was clear that the fabric's density influenced the visual perception. For example, a more open weave textile was perceived as thinner than a more densely woven textile with the same yarn diameter.

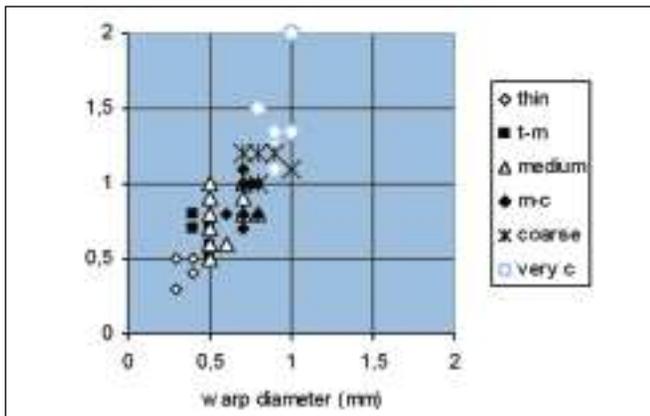


Diagram 1: Yarn Diameter in Relation to Perceived Textile Thickness, Lödöse Textiles. (Number = 56. One symbol in the diagram may represent more than one textile.)

As a comparison, Diagram 2 shows the same textiles using thread count as a measure of fabric thickness. This shows a weak correlation between thread count and visual thickness group and here the overlapping is much greater.

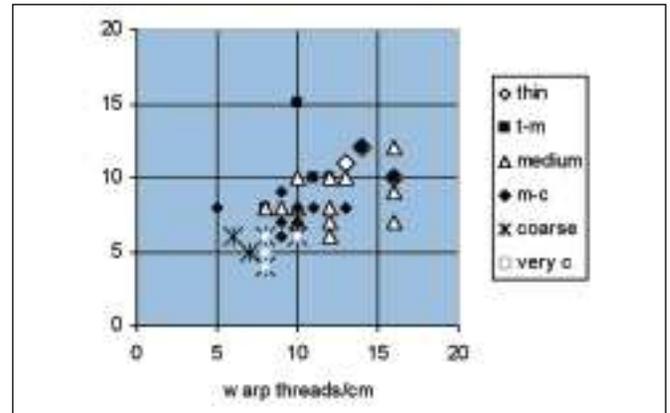


Diagram 2: Thread Count in Warp and Weft in Relation to Perceived Textile Thickness, Lödöse Textiles. (Number = 56. One symbol in the diagram may represent more than one textile.)

The diagrams made it clear that it was feasible to continue with yarn diameter as a parameter to describe thickness, and this was tested on the textiles from Trondheim and Mons Claudianus in the same way. The textiles from these two collections also made it apparent that the fabric's density affected how thickness was perceived visually. When applying the method to textiles from Mons Claudianus, it became clear that an additional category of 'very thin' was required, because that material contained many thinner textiles than those from the Lödöse and Trondheim collections.

Since fabric density clearly affected the textile's thickness, it was decided to include density in the work with thickness classifications. Four groups based on the cover factor were constructed:

Density Group	Cover Factor
open:	≤ 0.74
medium dense:	0.75 - 0.94
dense:	0.95 - 1.09
very dense:	1.10 \geq

These divisions have been determined by assessments made on both archaeological and modern hand- and machine-woven fabrics. Some fabrics have a cover factor higher than the theoretical maximum of 1.0. This can occur because the formula is based on the assumption that yarns are compact cylinders in the shape of a circle, but in reality, a yarn may be more or less elliptical. A hard spun yarn is more compact and circular relative to a loosely spun yarn. As a result, the actual cover factor of a fabric may not correspond to a theoretical value.

Classification Categories

The resulting system is comprised of both thickness and density. It is important to note that only woollen textiles have been analysed and that the classification system has not been tested on textiles made of other fibres.

There are seven thickness groups, ranging from very thin to very coarse. They are divided by a range equal to the warp yarn diameter (wa yd) plus weft yarn diameter (we yd).

<u>Thickness Group</u>	\leq	where $x = wa\ yd + we\ yd$ (mm)
very thin:	≤ 0.6	
thin:	0.6 - 0.9	
thin-medium:	0.9 - 1.2	
medium:	1.2 - 1.6	
medium-coarse:	1.6 - 2.0	
coarse:	2.0 - 2.4	
very coarse:	$2.4 \geq$	

If a textile's measurement is on the borderline between two groups then the fabric's density will be taken into account to determine which group it belongs to. If the textile is denser and has a cover factor of 0.90 or higher, it will be placed in the higher, or coarser, group. Conversely, if the textile is less dense and has a cover factor of less than 0.90, it will be placed in the lower, or thinner, group. For example, a textile with a warp yarn diameter of 0.3mm and a weft yarn diameter of 0.3mm, with a cover factor of 0.94, will be classified as thin:

wa yd 0.3mm + we yd 0.3mm = 0.6mm (very thin or thin categories), but the high cover factor of 0.94 places this fabric in the thin category

Taken together, the thickness and density groupings resulted in 28 different categories, from very thin, open fabrics (group 1a) to very coarse, very dense fabrics (group 7d).

Categories	very thin	thin	thin-medium	medium	medium-coarse	coarse	very coarse
open	1a	2a	3a	4a	5a	6a	7a
medium dense	1b	2b	3b	4b	5b	6b	7b
dense	1c	2c	3c	4c	5c	6c	7c
very dense	1d	2d	3d	4d	5d	6d	7d

A weakness in the grouping system is that it does not take into account the effect of different weaves on fabric thickness and density. A fabric woven in half-basket, basket, or twill weave will be slightly thicker than a tabby woven fabric. As a result, this method will be most reliable when textiles of the same weave are compared.

Textiles that have been heavily felted cannot be grouped using this method. Such textiles could be treated as a separate group and given only visual descriptions.

This method can be seen as a tool for describing and interpreting large finds of textiles where the similarities, in terms of technical description, are great, but where differences in texture and properties are visually apparent. In the Mons Claudianus material a majority of the textiles share the same technical features (tabby with twist direction s/s). In Löddöse, to give another example, common technical features are 2/1 twill, z/s. Here we need a more suitable tool to distinguish between the textiles, and the thickness and density grouping system can provide this.

Conclusion

Classifying textiles into visual groups allows a more complex description of each fabric's appearance and enables an examination according to a range of parameters that differ from those of traditional textile analysis. Handicraft knowledge can supply an important set of data that is not possible using technical analysis alone. The Pentagon model illustrates this, and can be used to understand a textile's complexity, how the different factors are related, and how a textile is the sum of the phases of its construction. Traditional methods, coupled with subjective analysis and handicraft knowledge, provide a holistic approach to understanding the textile, and insights into the skill and knowledge applied by early craftspeople.

The proposed classification of thickness and density makes it possible to describe and interpret textiles with similar technical descriptions but apparent differences in texture and properties. It also opens possibilities for categorising properties that are reflected by a fabric's thickness and density, and thus for further interpretation and fields of application.

This way, handicraft knowledge provides a useful tool towards the description and interpretation of archaeological and historical textiles.

Acknowledgements

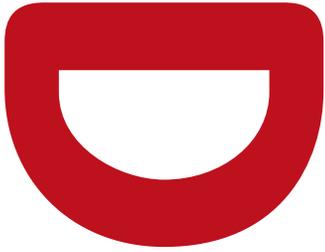
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