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Reviewed Article:

Some Uses of Experiment for Understanding Early Knitting and Erasmus' Bonnet

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Of Erasmus, prince of humanists (1466?-1536), no less than eight portraits from life survive – all eight in the exact same bonnet. A recently published investigation of this iconic garment (Kruseman, Sturtewagen and Malcolm-Davies, 2016) involved establishing a 250-year typology of the bonnet from iconographical sources, compiling technological and economic data from archival sources, and systematic experiments addressing numerous, various and

fundamental questions, from yarn characteristics in archaeological knitted textiles to the use (or not) of hatter's forms in the finishing of bonnets.

> Since the exact differences between modern and historic knitting are not yet well known, making reference samples with known characteristics is most usefully undertaken as an iterative process: the researcher makes the first set of reference samples on the basis of a more or less educated guess, then compares them to the original, corrects the guess, and starts over.

The experimental work directly related to the archaeological evidence turned out to be essential to the investigation, but much of it was too technical for the original publication. Experimental archaeology is its proper context, and I presented the posters this article is based on at the EXARC conference in Leiden in April 2017 (Kruseman, 2017a) and at the KEME symposium in Copenhagen in August 2017 (Kruseman 2017b). Thank you to the organizers and participants! Thank you also to Isis Sturtewagen and Jane Malcolm-Davies, my co-authors for the original article; to Toon Reurink for his help with the experiments; and to Letja Feis for special photography.

At the EXARC conference, I called attention to the fact that on a total of 56 papers and posters on the programme, only two were directly about clothing, with three more about related subjects (leather, textile production)[1] . This ratio, in my experience, is representative of archaeology in general. Yet every single living human being wears clothes, and it is usual for pre-industrial societies to invest as much labour in textiles as in food production: for a concise and vivid discussion of the place, importance and sheer size of textile production in prehistory, see Barber 1994. Speaking of this at the conference, I expressed the opinion that textiles and dress were badly underrepresented.

The usual excuse given is that since textiles are so fragile, archaeologists have nothing to work on. Those who want to ignore both the textiles themselves, and all indirect evidence pertaining to them, have been repeating this for so long that is has grown into a dogma and a self-fulfilling prophecy. Today, looking at the prodigious ingenuity with which archaeologists in general, and experimental archaeologists in particular, wrest evidence from the slightest pot shard or stone chipping, I can only feel it is high time for textiles to get a share of such serious, focused attention.

The two very modest sets of experiments presented here are a mere hint of how interesting and useful experimental work can be for the study of textiles and garments from the past (See Figure 1).

Why and how experiments can help understand early knitting

Since Erasmus' bonnet is known only from pictures, we started from the authentic portraits of Erasmus himself and went on to gather evidence from hundreds of pictures of bonnets dating from the 1320's to the 1530's, from archive material relating to the work of craftspeople who made the bonnets, and from archaeological textiles. As discussed in our 2016 article, all these sources indicate that the great scholar's bonnet was made of sheep's wool, spun, knitted, fulled, and moulded into shape by professional cappers (See Figure 2).

The data from archaeology were absolutely essential to our investigation, because they provide the physical evidence to anchor the indirect data from pictures and texts. In the absence of Erasmus' own bonnet, we looked for comparable bonnets in museum collections, and these turn out to be nearly all from archaeological sources.
Over a hundred knitted bonnets and many fragments survive from the 16th century. Close examination of such early knitted objects provides masses of interesting data, which in turn created more questions for the KEME project to investigate(Kruseman, Sturtewagen and Malcolm-Davies, 2016).

Among the surviving objects, the closest match we found was the bonnet in Figure 2, excavated in Groningen (NL), securely dated to 1500 – 1525[2] . It is very similar to Erasmus', but it seems to have a round crown, while the scholar's cap is characterized by its four ribs. Another interesting parallel came from the archaeological find from Dordrecht (NL) shown in Figure 3[3] ; this is a 16th century head covering of the type called 'coif' in English and 'huve' in Dutch. For a discussion of the English names for knitted bonnets and their component parts, see Malcolm-Davies and Davidson 2015 (See Figure 3).

To squeeze as much information as possible from the finds of archaeological knitted wool, experimental data are indispensable, and a lot interesting work is being done in this field. In the example of the investigation of Erasmus' scholar's cap, experimental comparison material can help to investigate what kind of wool/yarn was used, to explore the differences between bonnets made from woven fabric, from felt, and by knitting; to clarify the differences between modern and 16th C. knitting; to test hypotheses about the knitting pattern(s) and about the post-knitting steps (fulling, napping and shearing, shaping and moulding) (See Figure 4).

The two sets of experiments presented below address the first of these questions: the investigation of the basic "technical specifications" of archaeological knitted woollen yarn, the characteristics which define yarn in the production stage. Secondarily, we hoped to learn something about fibre choice and knitting methods as well, but primarily, we were investigating the woollen yarn used to knit the archaeological finds.

Its most basic technical specifications are:

- Is this yarn single or plied?
- Which way, S or Z?[4]

- How tightly is the yarn spun?
- How tightly is the yarn plied?[5]
- Are the wool fibres thick or fine?
- Is the wool long or short-staple?
- What is the diameter of the yarn?

Other basic technical specifications, not addressed here, include:

- What is the gauge of the knitted fabric (courses/length and wales/length)?
- What is the direction of knitting: from the apex of the cap to brim, or from brim to apex?
- How and where are the increases and decreases done?
- What method was used for casting on / off?

Looking at published descriptions of archaeological knitted artefacts, we found that they hardly ever give complete technical specifications, and sometimes nearly none.
In particular, where spinning and plying specifications were given, we found not a single author who said how they had been measured. Apparently, gauging these characteristics "by eye", the way craftspeople do, has so far been deemed sufficient, so that published specifications are only as reliable as the person who examined the artefact. A scientist, however, wants measurements that are reliable, verifiable and reproducible.

It would be more satisfactory if the author could say "the artefact was compared to this set of reference objects of known specifications, and found to be consistent with this, this, and that characteristic": the reader could then look up that reference and verify the correctness of the published description by reproducing the comparison.
The best set of reference objects would be one that provides comparison material truly suited to the artefacts. Since the modern knitter's eye is trained to modern knitting materials (See Figure 6), patterns and practices, which are different from the historical ones, and since expectations shape observation, the modern eye is liable to miss or misinterpret clues in historic artefacts. Comparison material that is as close a possible to the historical material can obviate this.

Since the exact differences between modern and historic knitting are not yet well known, making reference samples with known characteristics is most usefully undertaken as an iterative process: the researcher makes the first set of reference samples on the basis of a more or less educated guess, then compares them to the original, corrects the guess, and starts over. The feedback loop gradually generates both better data on the artefacts examined, and better comparison samples for future study of other historic artefacts.

This kind of referencing can be of great benefit to archaeologists who are not necessarily knitters[6] , or not experienced ones, but who do have to identify, describe and publish knitted textiles. Without some form of reference material, it is very hard for them to discern, analyse and describe what they see.

Upon these considerations, we decided to try and make ourselves a little visual reference material by spinning, plying and knitting wool to predetermined specifications, and comparing these samples to each other and to archaeological knitted wool. Two sets of such "knitted to spec's" samples are presented here.

- The first was intended to "map" the direction of the wool fibres within a knitted loop[7] ; applying the map to the yarn of excavated bonnets, we hoped to "read" its characteristics in some detail.
- The second was meant to trace the interaction between the different torsion forces in a knitted loop, providing insight into structures underlying the interplay of fibre, twist and ply on the knitted surface.

Both sets of experiments were intended as a starting point for further iterations, and emphatically not as an end product. This approach was vindicated by the conclusions, which raise at least as many questions as they answer.

Experimental data 1: Mapping the wool fibres in a knitted loop to read the yarn of excavated bonnets

The first illustration presents the data, i.e. the samples we used for mapping, in the different parts of the knitted loop, the direction and appearance of the fibres of the four most basic types of woollen yarn.[8]

The second illustration presents the results, i.e. the sketch map of the knitted loops and the fibre directions for these four basic yarn structures; followed by the application of this map to identify the structure of the yarns used to knit the Groningen bonnet and the Dordrecht huve.

The aim was to visualize the influence of this fundamental yarn structure on the finished knitted loops; fibre type and tightness of twist were only secondary considerations.

(See Figures 5 and 6, Mapping 1-001 and 1-002)

Experimental data 2: Interactions between the torsion forces within plied yarn and knitted loops

The second set of samples was meant to explore the interaction between the different torsion forces acting within a knitted loop, and to visualize the interplay of fibre, twist and ply on the knitted surface.

To the two controlled variables of the previous set:

- Direction of spin
- Direction of twist

We added the following factors:

- Known fibres
- Spun to a preset thickness, with a verified, even, twist (drop spindle, checking the twist every single time before winding the yarn)
- Plied with a verified twist (same method; the tightness of the twist is dictated by the that of the spinning)
- Samples knitted by the same knitter, in the same session, on the same needles

Aiming for maximum contrast in a small set of samples, I took the shortest, finest wool I had available (a Chubut merino from Argentina, for which the supplier claims a 16µm fibre) to set off against what modern hand-spinners in the Netherlands call "gewoon schaap" ("just plain sheep"), the Tesselaar, which has a longish staple and a medium thickness.

From the Tesselaar, I made two yarns, one with low twist and one with medium to high twist, while the Merino, being so short, needed a high twist.

The following table summarizes the specifications of the 3 yarns

(1) Low twist / long fibre	(2) Medium-high twist / long fibre	(3) High twist / short fibre
Tesselaar	Tesselaar	Merino
medium to long fibre medium to coarse thickness springy	medium to long fibre medium to coarse thickness springy	short extremely fine extremely soft and pliable
The long fibres lend themselves well enough to spinning at low twist, though they make a stronger yarn at medium twist.	The long fibres can be spun at medium twist; high twist is unsuitable, making a weak single yarn, and causing it to wriggle and knot.	These soft fibres are too short to spin a low twist. Medium twist is just possible, but the optimum strength is at high twist. The number of fibres that can be packed into a 3/4 mm Ø single yarn at high twist is much higher than for the coarser fibres.

The results after spinning, plying, and knitting, are presented in the following illustration. The analysis of the interactions is easier to diagram than to explain in words, and is presented in Mapping 2-001, 2-002 and 2-003.

Conlusions from both sets of samples & comparisons

The first set of experiments can be considered successful. The yarn structure determinations of the Groningen bonnet and the Dordrecht huve indicate that the maps of the fibre directions in Z, S, 2z/S and 2s/Z yarns are adequate for identifying these yarn types in archaeological artefacts where the structure is not too badly obscured or damaged.

In the second set of experiments, the two samples made from the same wool, but spun and plied with different twist values, do not show a clear difference after knitting; therefore, they can not be used for a direct comparison to see how tightly a historical yarn was twisted, which is a partial failure.

This set did, however, succeed in mapping the different reactions of the two types of fibre to the torsion forces in the loops. The thick, long, springy fibres in (1) and (2) "resist" the torsion of the knitted loop and form an open structure; the plying angle stays sharp, close to the vertical, on the surface of the knitted loop. The short, fine, pliable fibres in (3) "yield" to the knitted loop and form a closed, filled structure. The ply angle of this yarn on the surface of the loop is open, approaching 45°.
This 45° angle is reasonably similar to the ply angle observed on the historical objects we examined; in contrast, the near-vertical plying angle is similar to that seen in the supplementary sample from loosely-plied industrial wool.

If we accept that a low ply angle is associated with medium-long, medium-thick wool, such as the Tesselaar of samples (1) and (2), we can use it as a symptom that such a wool may have been used, keeping in mind that it does not reveal whether the yarn was spun loosely or tightly. Obviously, the sample set needs to be systematically expanded and diversified to turn this supposition into a firm conclusion.

On the other hand, when short, fine fibres are used, medium to high twist is inescapably necessary in spinning, because if such fibres are not twisted tightly enough, they will escape from the filament – it's like braiding short hair. If we accept that high-twist spinning triggers high-twist plying, then if fine wool is used, the knitted surface will show a larger (i.e. more open) ply angle, as seen in our historical comparison material.

Therefore, we conclude from the second set of experiments that for further work to replicate 16th century knitted wool with a fine, velvet-like nap and a closed, opaque, filled-in structure, the most promising material is a short, fine, smooth wool fibre.

Summary

1. The maps of the fibre directions in Z, S, 2z/S and 2s/Z yarns are adequate for identifying these yarn types in archaeological artefacts where the structure is not too badly obscured or damaged.

2. For further work to replicate 16th century knitted wool with a fine, velvet-like nap and a closed, opaque, filled-in structure, the most promising material is a short, fine, smooth wool fibre.
3. The next iteration of samples knitted from yarn produced to exact specifications should refine and expand the sets of comparison samples.

1 From the EAC10 programme. I do not count one paper on costumed interpretation, which had to do with didactic methods and not with clothes as such.

2 At the time of writing, this bonnet is on display at the RMO (Royal museum of Antiquities) in Leiden (NL), in the section on the archaeology of the Netherlands. The bonnet was found in Groningen (NL), in the cesspit of the Latijnse school, excavation Singelstraat [find # 369T317]. Published descriptions: Zimmerman 1998, 2000 and 2007.

3 The coif/huve from Dordrecht [find # 0201.028.001] can be found online via www.archeologiedordrecht.nl/vondsten.

4 For a very full discussion of the SZ notation, see Splitstoser 2012.

5 For an explanation of the angles, and their standard values, I recommend the invaluable reference work by Irene Emery (Emery, 1966).

6 All archaeologists should know something about the difference between the different textile structures (not just weaving and knitting, but cording, needlebinding, felting...), at least enough to know which expert to call in. For the non-knitters who need some basics to better understand this article, ask the nearest knitter to show you what they're doing: no explanation is half as illuminating as the real, physical, 3D thing. As next best, try Wikipedia and go on from there.

7 In knitting, the term "loop" is to be preferred for describing the structure of the fabric, and "stitch" for the action of forming the yarn into a loop. The terminology to be used for describing archaeological knitware will be discussed in detail in ATR 2018.

8 Though modern knitting yarns are usually 3-ply, 4-ply or even more, we chose to make only samples of 2-ply wool in both these experiments. It is the most basic type of plied wool, the easiest to understand for the non-specialist, and by far the most common in published descriptions of archaeological knitware relevant to Erasmus' bonnet. Notably, in her analysis of the Groningen find complex, Zimmerman describes 17 objects in 2-ply yarn, against only two in 4-ply and one in unplied yarn (Zimmerman, 2007).

Keywords textile
methods & techniques
(re)construction
wool

Country the Netherlands

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Gallery Image

FIG 1. ERASMUS IN 1521, WEARING HIS ICONIC BONNET. DETAIL FROM A DRAWING BY ALBRECHT DÜRER. MUSÉE DU LOUVRE, PARIS [# RF4113-RECTO] & WIKIMEDIA

FIG 2. KNITTED BONNET EXCAVATED IN GRONINGEN (NL), 1500 – 1525. PHOTO BY ISIS STURTEWAGEN, WITH THE GENEROUS PERMISSION AND HELP OF CURATOR ANNEMARIEKE WILLEMSEN OF THE RMO LEIDEN.

FIG 3. KNITTED COIF (OR 'HUVE', IN DUTCH) EXCAVATED IN DORDRECHT (NL), 16TH CENTURY. COLLECTIE ARCHEOLOGIE, DORDRECHTS MUSEUM. FIND # 0201.028.001. ONLINE VIA WWW.ARCHEOLOGIEDORDRECHT.NL/...

FIG 4. A CLOSE-UP OF THE BONNET FROM GRONINGEN: BURIED FOR 500 YEARS, DISCOLOURED, DEFORMED, DAMAGED... DAUNTINGLY FRAGILE. PHOTO BY ISIS STURTEWAGEN, WITH THE GENEROUS PERMISSION AND HELP OF CURATOR ANNEMARIEKE WILLEMSEN OF THE RMO LEIDEN.

FIG 5. THE TOP OF THE DORDRECHT COIF APPEARS TO HAVE A REMNANT OF THE 'TOPKNOT' TYPICAL OF KNITTED BONNETS, AND CLEARLY VISIBLE IN THE PORTRAIT OF ERASMUS. COLLECTIE ARCHEOLOGIE, DORDRECHTS MUSEUM. FIND # 0201.028.001. ONLINE VIA WWW.ARCHEOLOGIEDORDRECHT.NL/...

FIG 6. THIS SAMPLE IS KNITTED WITH MODERN KNITTING WOOL; THE YARN IS 2-PLY, BUT IT IS LOOSELY PLIED, AND THE DIVISION BETWEEN THE PLIED STRANDS IS HARD TO SEE. THE YARN FOR THE SAMPLES, WITH APPROXIMATELY THE SAME DIAMETER (THICKNESS), WAS SPUN AND PLIED WITH A STRONGER TWIST FOR A BETTER APPROXIMATION OF WHAT IS SEEN IN THE ARCHAEOLOGICAL MATERIAL. ALL SAMPLES WERE SPUN AND KNITTED BY THE AUTHOR AND PHOTOGRAPHED BY LETJA FEIS

MAPPING THE WOOL FIBRES IN A KNITTED LOOP…

SPINNING twists the fibres around each other:

long, strong, shiny fibres, ▲ **Z spun** (Ø 0.8 mm)
▼ **S plied** (Ø 1 mm)

short, soft, matte, fine fibres, ▲ **S spun** (Ø 1 mm)
▼ **Z plied** (Ø 1,2 mm)

PLYING wraps the single strands around each other, relaxing the yarn, as the *torsion* added to the fibres by spinning is compensated by the *counter-torsion* of plying.

KNITTING forms the yarn into interconnected loops

▲ **1Z single yarn**.
The uncompensated twist in single yarn can distort the loops and skew the fabric, especially in long-staple, springy wool such as this sock, where the asymmetry persists after a decade of use.

▲ **1S single yarn**.
In this soft, short-staple wool, the skewing is less, but still, all the loops show one "leg" longer than the other.

▲ **2z/S plied yarn**.
The long-staple wool is springy and gives the knitting an equally springy quality and an open structure.

The boundary between the two plied strands is always more visible in one leg of the loop than on the other.

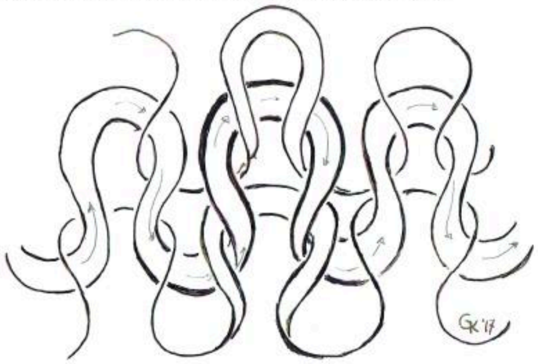
▲ **2s/Z plied yarn**.
The fine wool follows the loops with docility to form a dense, opaque knitted structure. The two "legs" of each loop are of equal length.

The pattern of the fibres is *mirrored* from S to Z ply, but *identical* whether seen with or against the direction of knitting.

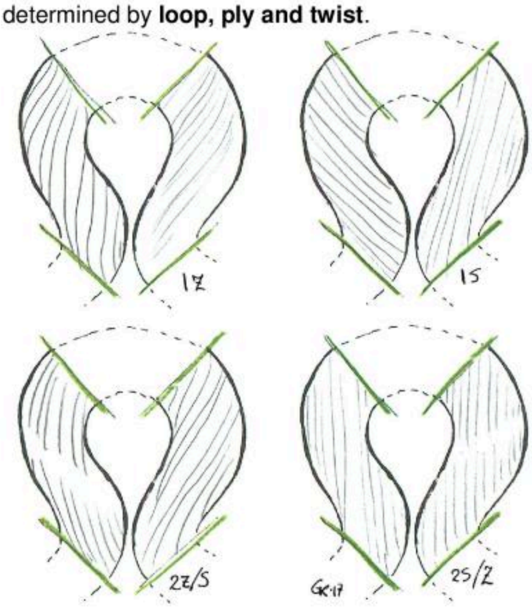
MAPPING 1-001 ALL SAMPLES WERE SPUN AND KNITTED BY THE AUTHOR AND PHOTOGRAPHED BY LETJA FEIS.

...TO READ THE YARN OF EXCAVATED BONNETS

THE **STRUCTURE OF KNITTING**:
each loop is connected to its 4 neighbours.



THE **DIRECTION OF THE FIBRES**:
determined by **loop, ply and twist**.



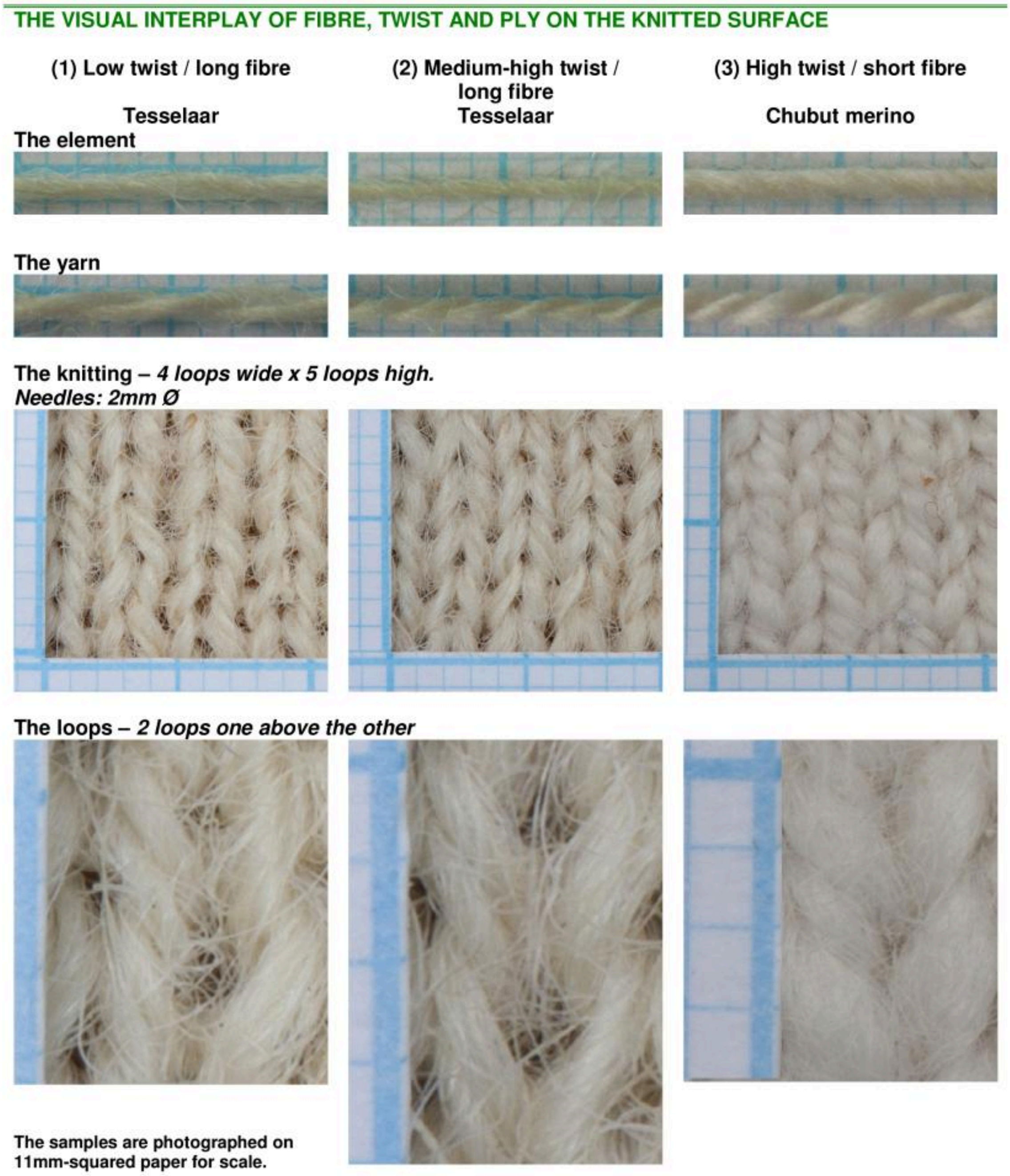
Using this map on digitally enlarged photos of the two finds, the following yarn structures emerge:

GRONINGEN BONNET

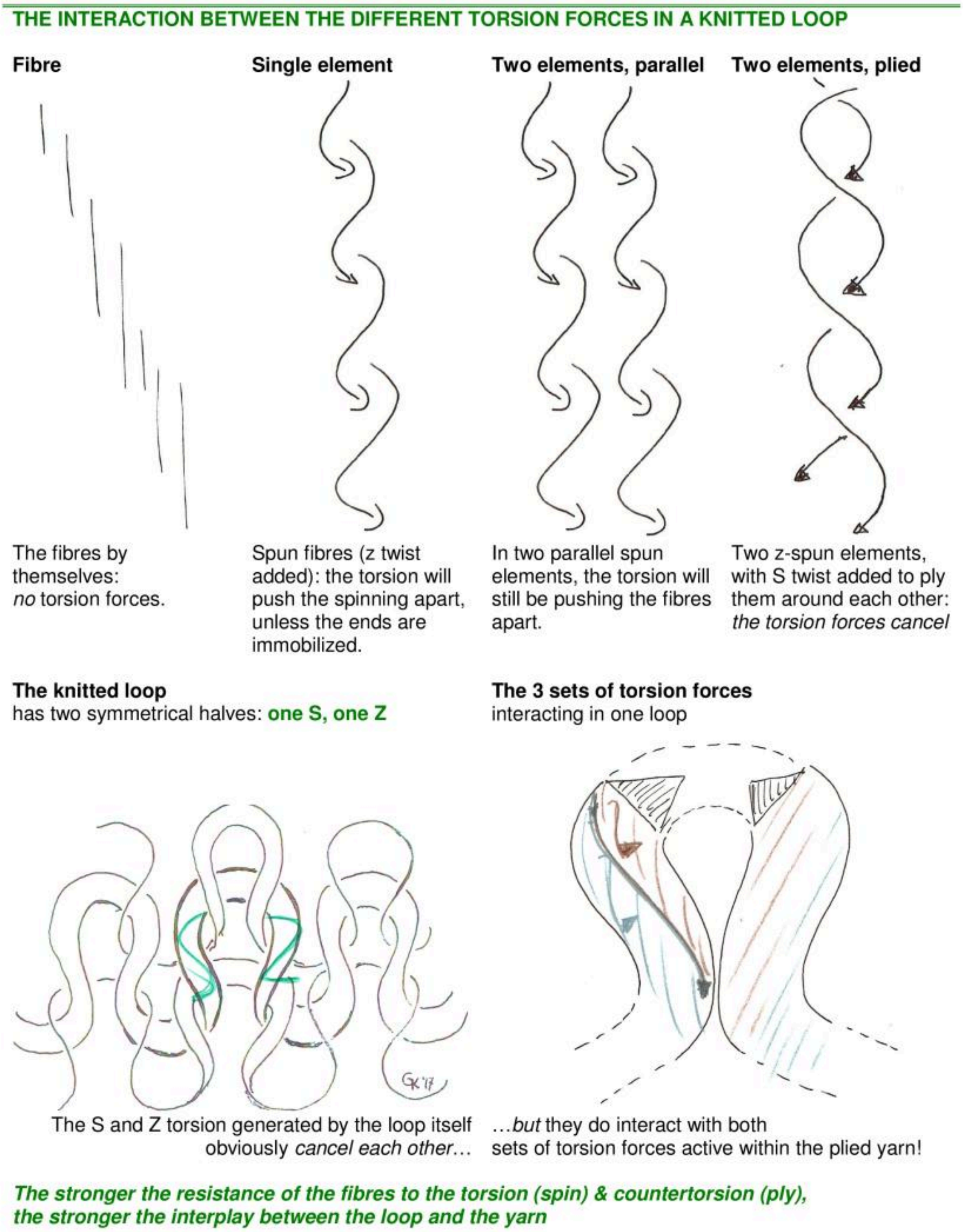
DORDRECHT HUVE

SPIN/PLY: both objects are made from two-ply wool, 2z/S.
FIBRE: the Groningen bonnet may be of finer, softer wool than the Dordrecht huve, judging from the greater opacity of the fabric of the bonnet, and from the more springy interaction of the loops in the huve.

MAPPING 1-002 DRAWINGS BY THE AUTHOR.



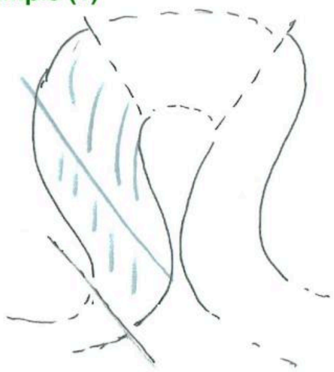
MAPPING 2-001 ALL SAMPLES WERE SPUN AND KNITTED BY THE AUTHOR AND PHOTOGRAPHED BY LETJA FEIS.



MAPPING 2-002 DRAWINGS BY THE AUTHOR.

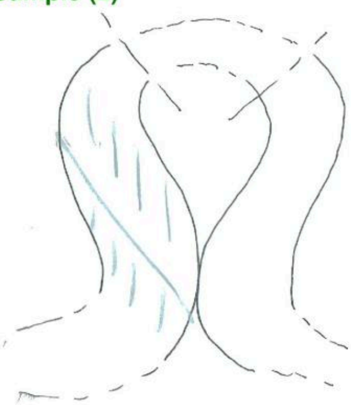
THE THREE DIFFERENT YARNS = THREE DIFFERENT REACTIONS TO THE INTERPLAY OF THE THREE TORSION FORCES

Sample (1)



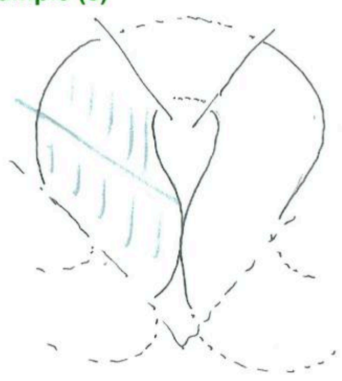
As expected, the S ply of the yarn shows up clearly on the S-half of the loop, but the low…

Sample (2)



… or high twist/ply does not make much difference: samples 1 and 2 give practically the same appearance.

Sample (3)



The finer fibres however cause the high-twist yarn to behave differently; it does not "resist" the looping of the knitted stitch and so the ply-angle shows up much more strongly.

MAPPING 2-003 DRAWINGS BY THE AUTHOR.