Reviewed Article:

Reconstructing Ötzi's shoes

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Ötzi the Gletshermummie, Ötzi the Iceman and Tisenjoch are the names we gave the man that walked in the Alps 5,300 years ago. Thanks to the Ötzi museum in Bozen/Bolzano, Italy, I had the opportunity to reconstruct Ötzi's shoes. For making the shoes I used a flint knife, for both shoes I mostly used one knife. The net is made by hand so not many tools were needed to reconstruct the shoes.

The book that has detailed information about Ötzi's clothing is *Kleidung und Ausrüstung der Kupferzeitlichen Gletschermumie aus den Ötztaler Alpen* (Egg and Spindler, 2009). This book

was my source of information for photos and reconstruction drawings as I planned to reconstruct the footwear worn by Ötzi. The drawings used a scale to determine the right size. In the reconstruction drawings from this book, I added the sizes and marked some areas for investigation.

In the Ötzi museum in Bolzano we were able to take a good look at the 'real thing and the museum provided us after the latest research data on the shoes.

> I was able to feel how the shoe fits because I have the same size, and that experiential element added a lot in making this reconstruction. The shoes feel steady around the foot and even after making the net, there is enough space left to put in the grass. I was surprised by the effective fit due to the perfect model of the net structure.

Description of the shoes

The shoes consist of a bearskin sole, deerskin upper leather attached to the sole with a thin cow hide strap. A thick cowhide strap is woven into the sole so the edge of the sole was pulled up a few centimetres.

Inside the shoe is a lime bast net structure that holds the grass placed in the shoe for insulation and to give stability to the shape of the foot and the shoe. Under the soles there are leather strips.

The shoes

The right shoe was still on Ötzi's foot when he was found. It was an oval piece of grass covered with heavily degraded deerskin fur, worn with the hair-side out. Only on the front part of the shoe the leather was preserved, as the heel part is missing. Inside the shoe there was a lime bast net structure using grasses for insulation. The leather upper is attached to the sole with a 0.5 cm wide cowhide strap that was woven into slots of the sole. The sole is made from bearskin with approximately 1.5 cm wide slots in which a cowhide strap is woven so the edge of the sole is pulled up around the foot by a few centimetres. The lime bast net structure is attached to this same cowhide strap. This net structure keeps the insulating grasses in place, giving stability to the shape of the foot and to the shoe itself.

It was observed that the net structure was repaired in several places with leather straps. To sew the upper leather into the sole, an approx. 0.5 cm wide cowhide strip is woven in the same slits of the sole. Several holes were cut in the deerskin upper and a lime bast shoelace run through them, used to close the net structure as well as the leather shoe.

Across the sole a crossing leather strap is attached to the thick cow skin strap. The ends of the cross straps are lengthened and knotted using a narrower leather strap.

The right shoe provides a lot of information for reconstructing the shoe as it provided an impression of the sole pattern with the slits and the straps. We can see how to shape the shoe, how the net structure and the upper leather were attached as well as the structure used in the lacing.

Only the bast net structure and grasses, which were much better preserved than the right shoe, remain on the left shoe. The heel is absent and only small traces of fur remain on the area of the toe. The net structure is attached to the cowhide strap that runs around the sole and adapts very well to the shape of a human foot. The basic net structure consists of 15 vertically arranged longitudinal strands forming a loop at the bottom. The strands consist of Z-twisted strands with a diameter between 2-4 mm that are S-plied in a cord with diameter 5-6 mm.

The horizontal, loosely S-twisted threads 2-3 mm, knotted in at regular distances with a single finger knot, makes it into a net structure.

Two Z-twisted threads with a diameter of 3-6 mm in an S-plied rope, 52 cm long served as a shoelace. It tapers from 7 mm at the beginning to 3 mm towards the end.

Lime bast

The material used for the net is the fine 1-2.5 -meter-long inner bast layers of the lime tree.

After cutting down a lime tree in spring, the bark is removed and put in the water for about 6 weeks. The inner layers of the bark are called bast and are frequently used in prehistoric Europe in a wide variety of artifacts in various techniques. *The Voice of the Lime Tree* (EXARC, 2022) is a film from Eva IJsveld about the processing of the lime tree bark in order to make a reconstruction of a mantle found at prehistoric lake settlements in Switzerland (Harb and Bleicher, 2016, Figure 359).

The net structure

The basic structure of the net is made using a plying technique. (See Figures 6a-g) It comprises a rope with 15 cords hanging down. The structure can be made by plying two bundles, with one of the bundles forming the pendant cords. The net structure itself consists of Z-twisted strands with a diameter 2-4mm that are S-twilled in a cord, with a diameter 5-6 mm. This process can be done purely by hand, as no tools or frames are needed. Then the basic structure of the net can be attached to the sole. The horizontal threads which make up the matrix of the net structure can be added after attaching the basic structure to the sole. Both shoes appear to have a similar structure except for small differences in the horizontal binding threads and some repairs as when the left net is cut open and spread out flat, it has the same structure as the right shoe.

The leather material

The leather of the shoes is from three different animal species, in itself illuminating the lifestyles of the Alpine peoples of the time. The soles of the shoes are made from brown bear skin, the upper and back of the shoes are made from roe deer skin and the straps are made of cowhide. We know from the leather clothing that the flesh sides have scraping marks on the skin and that they were tanned with fat which may have been derived from brain, offal and bone marrows. The pollen found on the clothing had shrunk, indicative of the process of having been smoked for some time (Egg and Spindler, 2009, p.59).

While this information on fat tanning and smoking hides applies to Otzi's clothing, the same process is likely to have been used for his shoes. We chose to use rawhide in the reconstruction of the sole and the cow hide straps because rawhide is more water-resistant. The deerskin upper was tanned with brain fat and marrow and smoked afterwards, to maintain authenticity.

The cow hide strapping

A comprehensive mitochondrial analysis of the Tyrolean Iceman's leather mentioned (O'Sullivan, et al., 2016) that the leather straps used to sew the net and the upper leather was made from cowhide. The cow hide connective strips were prepared first by being scraped and washed, then stretched to make them more pliable.

Stretching rawhide when it is drying pulls the fibres open and a little apart from each other, increasing pliability and making it more workable, but still more dense and stronger than leather. Cow hide has a tight fibre structure making the cords very strong. A wide leather strip, some1–2 cm wide was cut from cowhide and used for shaping the sole and attaching the net structure, while straps some 0.5 cm wide were cut for sewing the upper leather.

The sole

We know from the same source (O'Sullivan, et al., 2016) that the shoe soles are made of brown bear (*Ursus arctos*) skin, with the raw skin scraped to remove meat and fat. For our reconstruction, the skin was washed, stretched and dried, to make the rawhide a bit more malleable. After processing and drying the raw skin, it was also smoked to both preserve the leather and make it less sensitive to water, as the smoking also keeps the leather soft after getting wet. The hairs on the inside feel slippery if pointed to the back, even if hay is inserted it feels slippery so while cutting the pattern of the sole the hairs are pointed to the front for a better grip. It is key to note that bearskin leather is very pliable and easy to work with. It can easily be cut with a flint stone knife to make the 30 slits, about 1.5 cm wide, around the edge of the sole (See Figure 12).

Attaching the basic net structure to the sole

An approx. 1.2 cm wide leather strap was cut from cowhide and used for shaping the sole and attaching the net structure. When the strap is tightened, it gives the edge stability. The base of the net was attached at the same time as the strap is woven in. The lengths of the net ropes could then be adjusted to the foot by giving them an extra twist before attaching them to the sole.

Attaching the horizontal treads to the basic net structure

The horizontal threads that make it a net structure can be added after attaching the base structure to the sole. The loosely S-twisted threads 2-3 mm in diameter are knotted at regular distances with a single finger knot. Fitting it onto my own foot made it very easy to make the net fit exactly, since Ötzi also took a size 38 (UK 5) so I was very lucky to be able to feel the fit myself.

Figure 17 shows the numbers of the strands. The binding of the horizontal treads is starting at point A on strand one of the basics structure working around the foot and ending on strand 15. The second binding starts at point B on strand 15 and continues to strand one and then working further around the foot. The first piece of this second binding connects both sides of the net structure and makes the step-in for the shoe. The third binding starts at point C on strand 15 and so on, but the net is not totally made with this method. At the front of the shoe the threads are going up and down to fill in open spaces.

Insulating grasses

I filled the shoe with grasses to be sure that this insulation would fit in using the net structure sizes. The grasses were picked on a mountainside of the area where Ötzi had been walking.

Whether it is exactly the right kind of grass I do not know but the grasses feel soft enough for walking on.

There are different species of grasses determined in the shoes, such as *Brachpodium pinnatum*, *Nardus stricta, Festuca* types 1, 3 and 4, and an *Agrostis* type. Most of these grasses grow in the high Alps, only *Brachpodium pinnatum* occurs only in valleys (Egg and Spindler, 2009, p.64).

It seems that the Iceman stuffed grass into his shoes in the valleys and replaced or completed this thermal insulation on his way through the mountains.

The deerskin upper leather

For the upper and heel part of the shoes we used the summer skin of a deer. Skins of animals become a little thicker in summer, while the fur gets thinner. In winter the skin gets thinner and the hair thicker (Scherpenzeel, pers.comm, 2022). From the original find of the shoe, we

could see some thin hair attached to one of the cowhide strings, this leads us to think that Ötzi might have used a summer skin for his shoes as well.

The raw skin was scraped then treated with a solution of water, brain and bone marrow (Egg and Spindler, 2009, p.59). Both brain and bone marrow contain fats that easily mix easily with water. When drying the brain and bone marrow fats are absorbed by the skin The fats bond with the fibres of the skin which makes it easier to stretch the skin whilst drying and making it soft. To make the leather more water resistant it was also smoked.

The right shoe provided information about the shape of the upper leather as well as how it attached to the sole. Before cutting the pattern out of the skin, the direction of the hairs needed to be considered as the direction makes sure water drips off.

The shape of the pattern is important for the shape of the shoe and a good fit. An approximately 0.5 cm wide cowhide strap was used for stitching the upper leather onto the sole. How exactly the skin was sewn is not clear from the actual artefact, due to lack of preservation.

After some testing I found that folding the edge and sewing through two layers gave a good result. This method fills up the gaps between the relatively wide spaces of the stitching and the double seam layer, helping to prevent water coming in. Stitching through two layers is stronger too. After folding the edge, the hairs were pointing upwards, to prevent them catching water drips, and the hairs on the edge were removed.

The same slits in the sole were used for both cowskin straps, only the stitching was opposite.

This way of stitching with two straps makes the shape of the shoe steady and wearable.

The heel

As the heels were missing on both shoes so it is not certain if this part of the reconstruction is correct. Ötzi was wearing leggings, and the leggings had an extra-long piece of deerskin attached to the lower edge. This piece was left under the shoelace and under the upper leather.

The legging was first put in the shoe and then the shoe was laced up. By tucking the legging into the shoe, a closed surface was created between shoe and legging, preventing snow or water from entering.

Because we see this is so efficiently performed in the front of the shoe, I suspect that the heel would be closed also. The hypothetical heel needs to be equally as high to cover the net structure and make a closed surface with the leggings, just as was done in the front of the shoe. Walking in the Alpine region, with unpredictable weather systems and sometimes

dramatic storms of rain and snow, it is likely that the original maker would want to close the heel as well.

After talking to the curatorial staff at the Ötzi museum, it was discovered that a piece of cow leather sewing strap was found on the heel part as well. The heel part is sewn in the reconstruction in the same way as the upper leather in the front part. (Tumbler and Aldegani, pers. comm., 2022).

Attaching the sole strap

Under the sole, a cowskin strap was attached approx. 0.8 cm wide and 17 cm long (dark blue line Figure 11). The strap is attached with smaller leather strips. In the reconstruction I used the ends of the small 0.5 cm wide strips used for sewing in the upper leather. The 1.2cm wide strip that I sewed into the sole (light blue line Figure.11) was long enough to cross the back of the shoe and create a binding in the back of the shoe.

Another discovery of shoes with bindings under the soles are the 5000-year-old Swiss lime bast shoes found in lake dwellings in Maur-Schifflaende. (Hubert, pers. comm., 2020-2021)

In the reconstruction by Eva IJsveld, Photo 34 we can see the bindings. The Swiss remains show different methods of bindings; some only had a few while other soles were totally covered with bindings as in the photo (See Figure 34).

Lacing

The leather of the left shoe was missing so the shoelace could have held the leather as well as the net structure. Assuming the lacing in the finding was done the same way as it is in the photo, it (See Figure 35) is possible to make a start like this in lacing the shoe. The lace in the left shoe is long enough to reach around the heel, which feels really steady and pulls the leather of the heel part close to the foot.

However, the lacing of the right shoe is different from the left shoe. The yellow lines in Figure 2 show that lacing. It holds together both the net structure and the upper, but also connects the leather strap in the red circle and the purple lined leather strap. The lace in the left shoe could be placed around the heel, but the lace of the right shoe is not long enough to reach around the heel as well as the leather straps on the outside.

The method of closing with a loop in the string and the end pulled through is quite a striking detail (See Figure 38 a). In the reconstruction I used the lacing of the left shoe with this method of closing the shoe (See Figure 38 b)

Plausible addition to the shoes

In the red circle in Figure 42 there is a leather strap visible. The strap is 17 cm long, 1.5 cm wide and has two slits on the end. The strap is bent and a lime bast rope runs underneath. The reconstruction drawing from Egg and Spindler (2016, p.65) shows that this strap is attached through a cut in the cowhide strap in the sole. It is not clear in the reconstruction drawing or in the text, if this leather strap is tied through only the strap or through both layers strap and sole. If attached through both layers it could be very useful to lock both layers in place.

The rawhide is the strongest material used in the shoes. It could be very useful for extra bindings over the foot or even for attaching snow boots under the shoes. A lime bast rope is used to tie underneath these straps on both sides. Probably the shoelace that is attached to the net structure was used to tie these straps.

In the final reconstruction I chose not to add this leather strap as it is found on the repaired right shoe, so it could well be explained as a repair itself. I was uncertain if I needed to cut through only the cowhide straps or through both layers of the shoe. (I chose both layers when attaching them, rightly or wrongly). It is a change in the looks of the reconstruction and I am not sure how to use them and would add more uncertainties to the reconstruction.

Another possibility that could work well would be using these straps to put snow boots under the shoe. Snowshoes have been found close to the place where Ötzi was found in the South Tiroles Ötztal. These snowshoes are even older than Ötzi, dating back to 3800-3700 BC (Il Museo Archeologico dell'Alto Adige)

About the making of the shoes

I was able to feel how the shoe fits because I have the same size, and that experiential element added a lot in making this reconstruction. The shoes feel steady around the foot and even after making the net, there is enough space left to put in the grass. I was surprised by the effective fit due to the perfect model of the net structure. After adding the horizontal threads, it became a steady structure. The inserted grass feels soft, and I do not feel the net structure while wearing them.

For making the shoes I really used a flint knife, as the materials were easy to cut. The suppleness of the bearskin was easy to work with, the thick layer of hairs gives good insulation and a soft feeling to walk on. After filling the shoe with the grass, you do not feel the hairs of the bear skin anymore but they do insulate efficiently. One little part of the net structure became a favourite part because it is so useful (See Figure 50) It is the third horizontal thread added in the net structure. It acts as a step-in opening that needs to be of good length.

It was a beautiful job reconstructing these shoes!

Thanks to Niels Scherpenzeel who professionally provided the right material and information and thanks to Margit Tumbler and Nico Aldegani of the Ötzi museum.

Constructing the shoes requires a good pattern and technical skills and crafts in leather and fibres to make them fit well. Using similar materials and tools, facing the same steps in the construction of these shoes brings me close to the people who made Ötzi's shoes. The cleverness and skills of prehistoric people always amazes me. In making the reconstruction there are lots of uncertainties that need to be solved. There can be many ways to shape the pattern, make the heel, the lacing or the holes in the upper leather. I would never say this reconstruction is definite, I would rather say this is one of the possibilities.

Keywords Ötzi
shoe

Country Italy

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Tumbler, M. and Aldegani, N., 2022. Reconstruction based conversation about materials and reconstruction and looking at the real findings. Are there indications of possible sewing material for the heel. [conversation] (Personal communication 28 October 2022)

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Gallery Image

FIG 1. SHOES, EGG AND SPINDLER (2009, COLOUR PLATE 1)

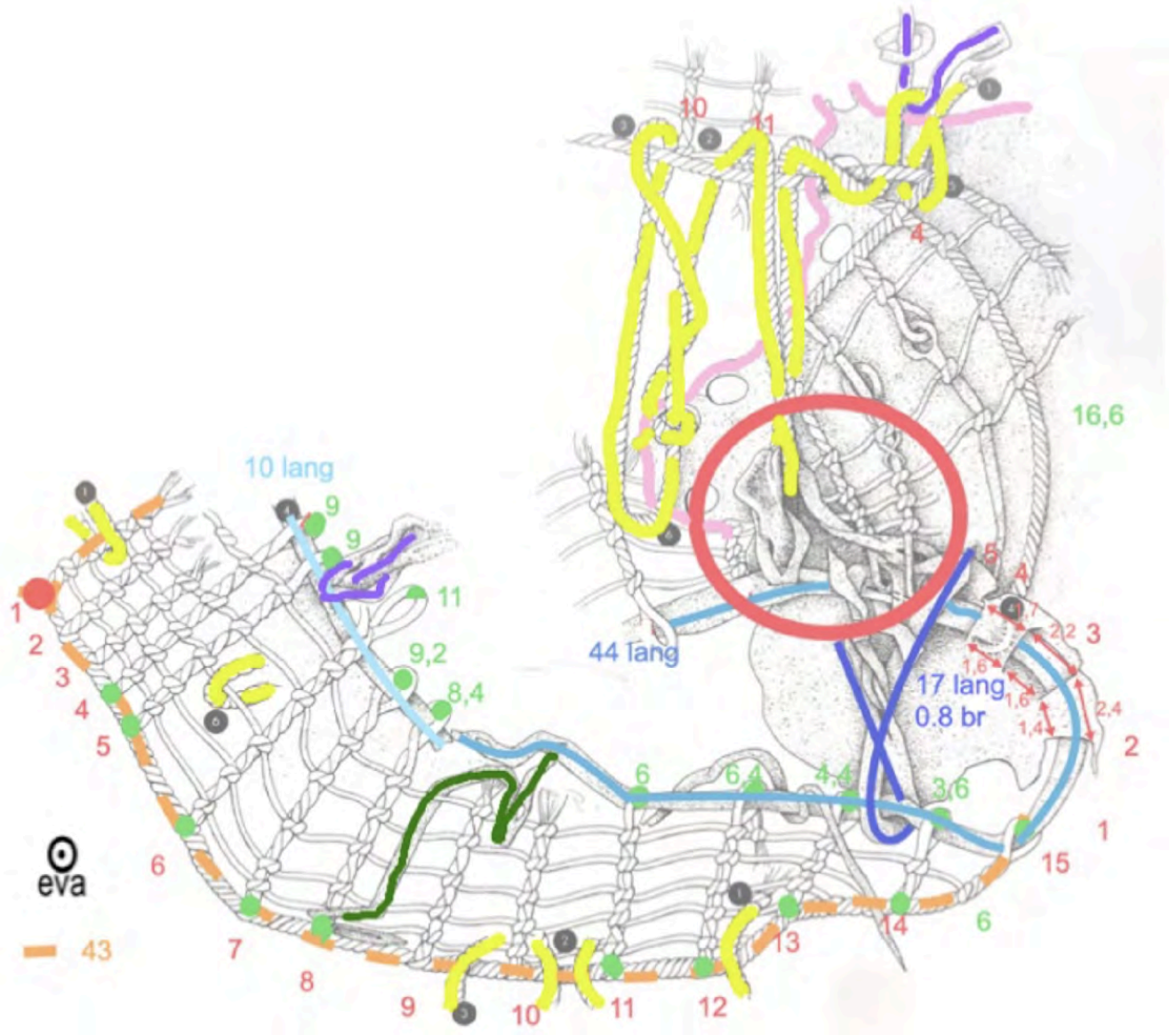

FIG 2. RECONSTRUCTION DRAWING FROM EGG AND SPINDLER (2009, FIG. 18) FILLED IN COLOURS AND NUMBERS BY EVA IJSVELD

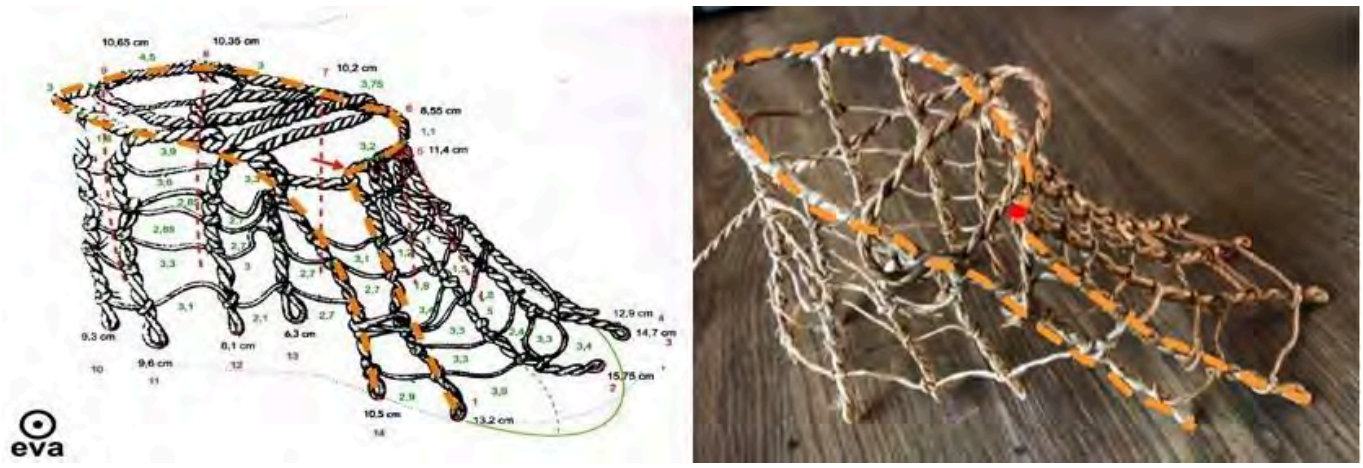

FIG 3. LEFT SHOE, INSIDE FOOT, DRAWING FROM EGG AND SPINDLER (2009, P. 69) WITH ADDED SIZES AND PHOTO BY EVA IJSVELD

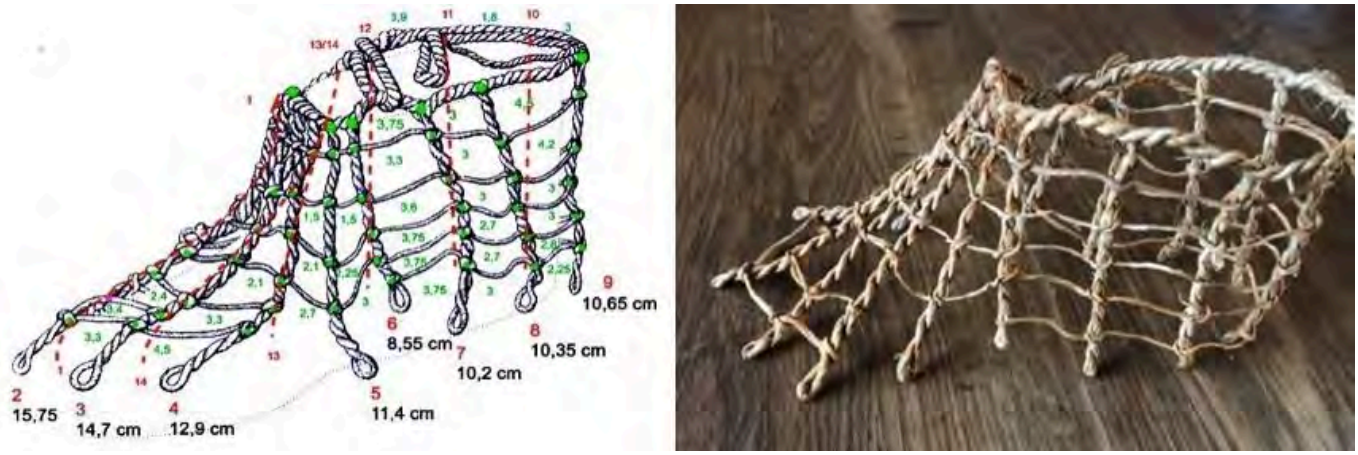

FIG 4. LEFT SHOE, OUTSIDE FOOT, DRAWING FROM EGG AND SPINDLER (2009, P. 69) WITH ADDED SIZES BY EVA. PHOTO BY EVA IJSVELD

FIG 5. LIME BAST SUPPLY. PHOTO BY EVA IJSVELD

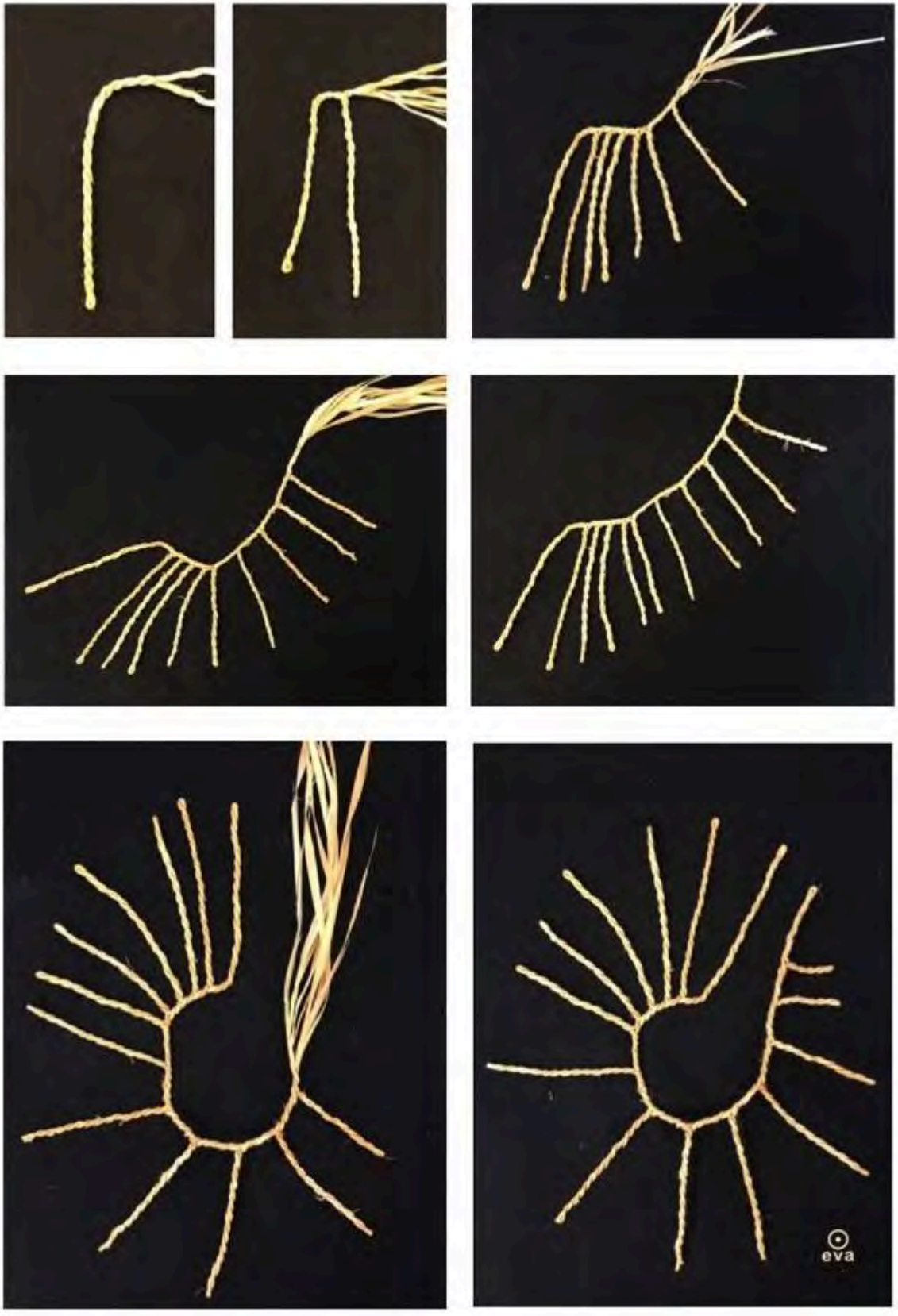

FIG 6. MAKING OF THE BASIC NET STRUCTURE IN PLYING TECHNIQUE. PHOTO EVA IJSVELD

FIG 7. MATERIALS TANNED. PHOTO BY NIELS SCHERPENZEEL

FIG 8. COWHIDE STRIPS, PHOTO BY NIELS SCHERPENZEEL

FIG 9. BEARSKIN, HAIR AND FLESH SIDE. PHOTO NIELS SCHERPENZEEL

FIG 10. CUTTING OF THE BEARSKIN WITH FLINT STONE. PHOTO BY EVA IJSVELD

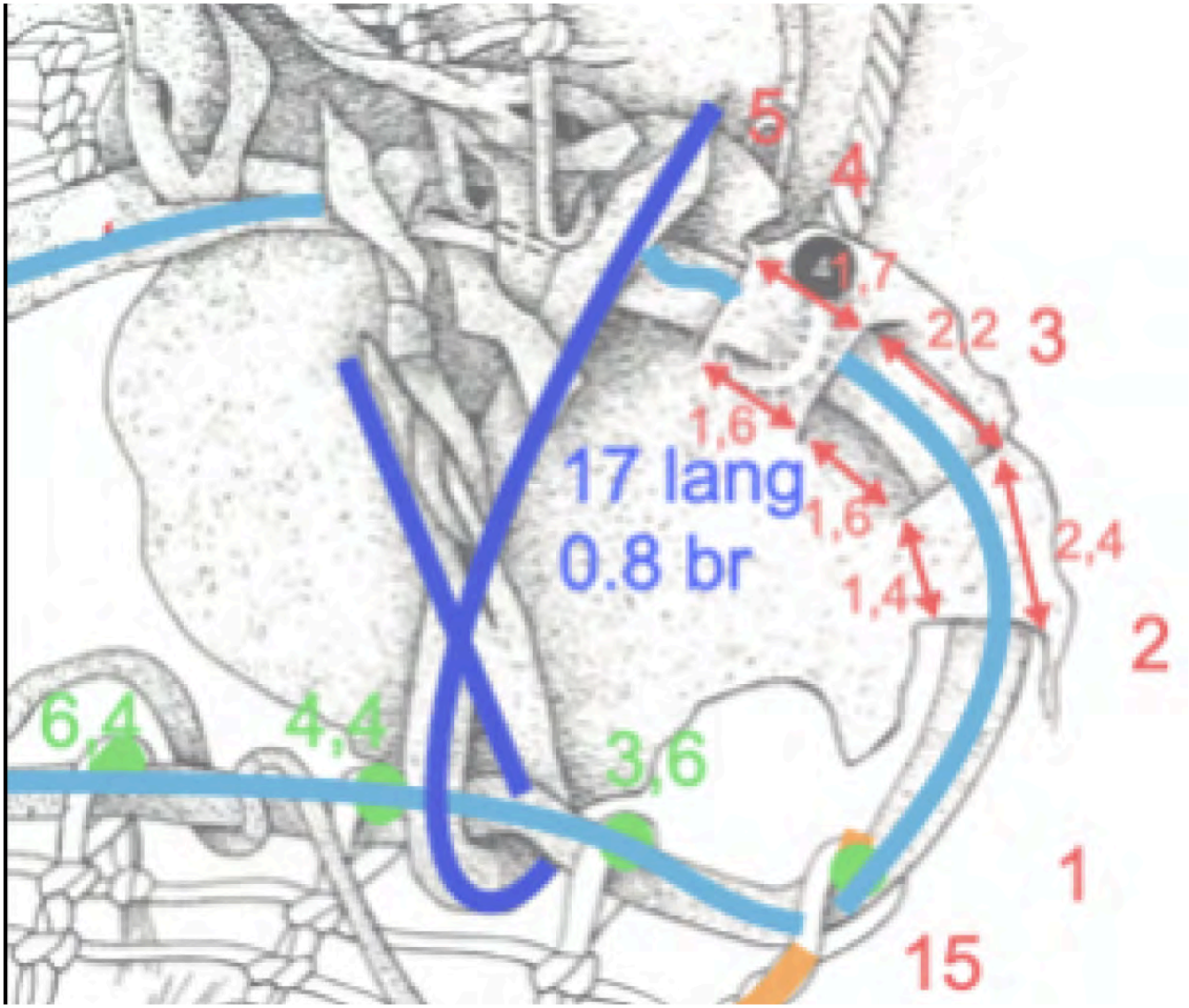

FIG 11. DETAIL OF A RECONSTRUCTION DRAWING FROM EGG AND SPINDLER (2009, FIG. 18) WITH ADDED LINES AND NUMBERS BY EVA EVA IJSVELD.

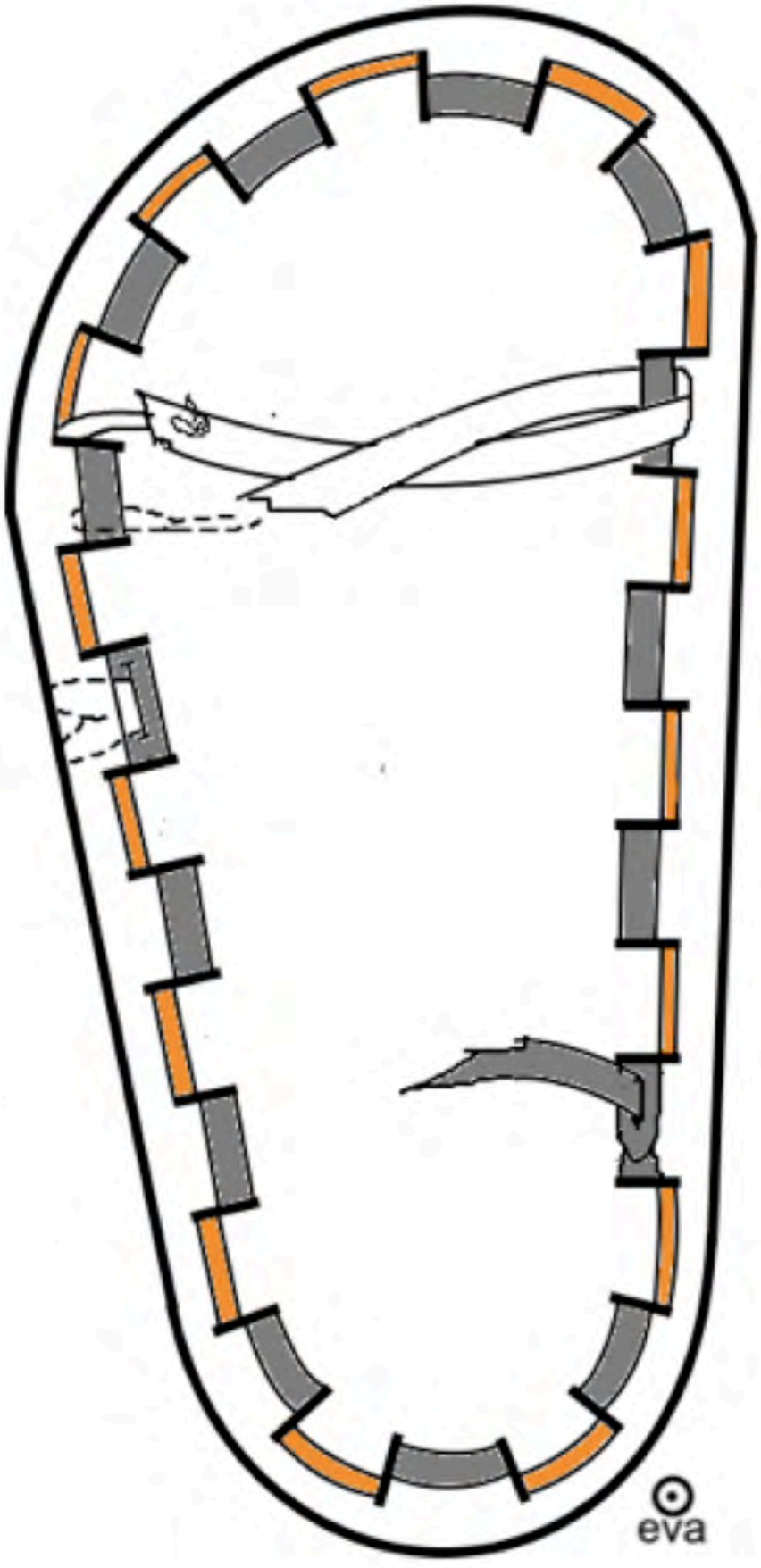

FIG 12. DRAWING OF THE SOLE PATTERN EVA IJSVELD

FIG 13. LOOPS IN BASIC NET STRUCTURE IN A TEST SHOE, PHOTO BY EVA IJSVELD

FIG 14. LOOPS OF THE BASIC NET STRUCTURE ATTACHED IN BEAR SKIN SOLE. PHOTO BY EVA IJSVELD

FIG 15. NET STRUCTURE IN BEARSKIN SOLE FRONT VIEW. PHOTO BY EVA IJSVELD

FIG 16. BASIC NET STRUCTURE ATTACHED TO SOLE. PHOTO BY EVA IJSVELD

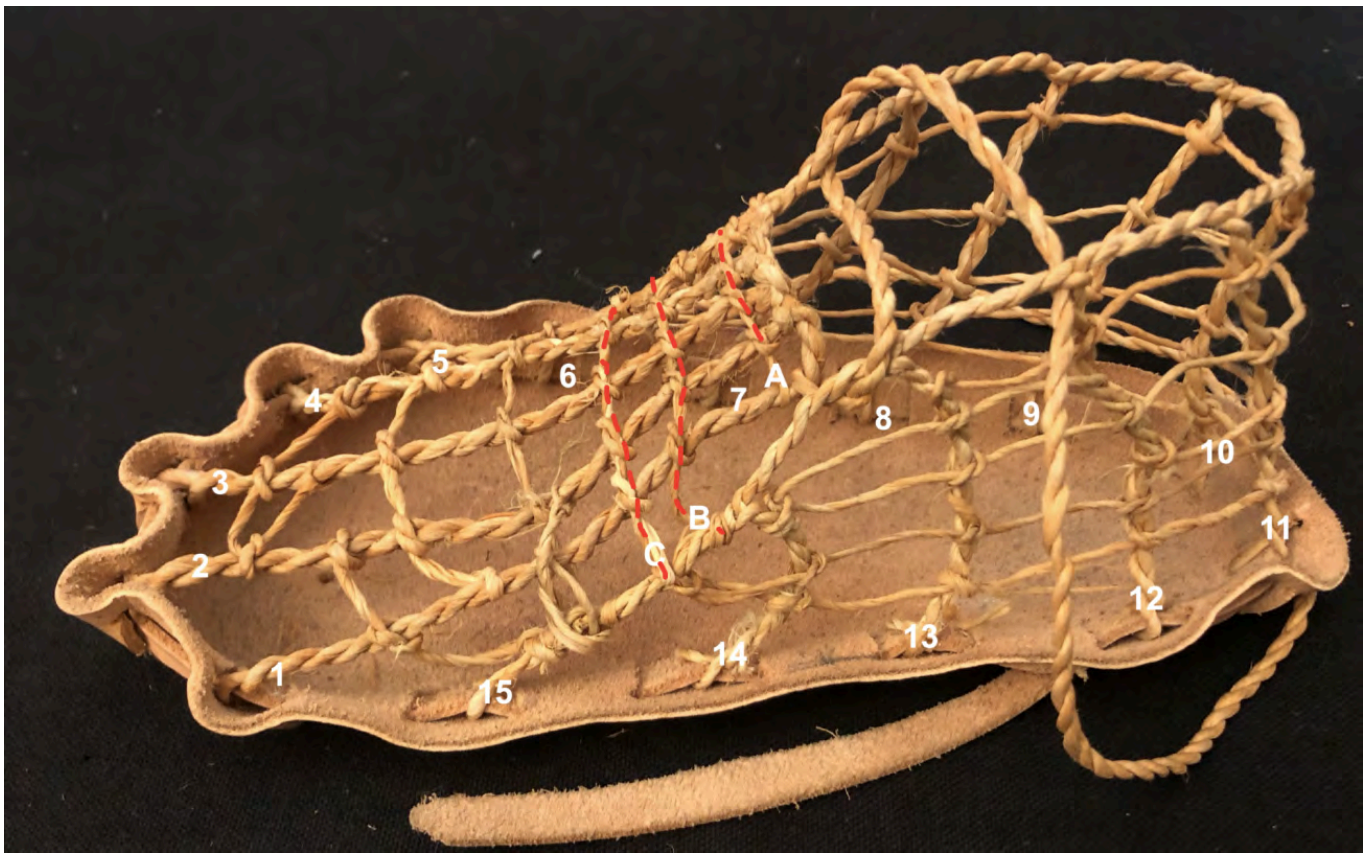

FIG 17. PHOTO OF TRY OUT SHOE WITH DRAWING OF HORIZONTAL THREADS. PHOTO BY EVA IJSVELD

FIG 18. MAKING THE HORIZONTAL THREADS OF THE NET STRUCTURE. PHOTO BY EVA IJSVELD

FIG 19. BOTH SHOES WITH FINISHED NET STRUCTURE. PHOTO BY EVA IJSVELD

FIG 20. DETAIL OF THE NET STRUCTURE WITH SINGLE FINGER KNOTS. PHOTO BY EVA IJSVELD

FIG 21. GRASSES IN THE NET STRUCTURE. PHOTO BY EVA IJSVELD

FIG 22. PATTERN OF THE UPPER LEATHER FLESH AND HAIR SIDE. PHOTO BY EVA IJSVELD

FIG 23. ATTACHING THE UPPER LEATHER TO THE SHOE. PHOTO BY EVA IJSVELD

FIG 24. STITCHING UPPER LEATHER WITH COWHIDE STRIP. PHOTO BY EVA IJSVELD

FIG 25. STITCHING INSIDE THE SHOE. PHOTO BY EVA IJSVELD

FIG 26. FRONT PART UPPER LEATHER SEWN IN. PHOTO BY EVA IJSVELD

FIG 27. FRONT PART UPPER LEATHER SEWN IN. PHOTO EVA IJSVELD

FIG 28. DETAIL BOTH STRAPS SEWN IN. PHOTO BY EVA IJSVELD

FIG 29. SEWING IN THE HEEL. PHOTO BY EVA IJSVELD

FIG 30. STITCHING THROUGH TWO LAYERS. PHOTO BY EVA IJSVELD

FIG 31. CLOSING ON THE OUTSIDE OF THE FOOT. PHOTO BY EVA IJSVELD

FIG 32. CLOSING AT THE INSIDE OF THE FOOT. PHOTO BY EVA IJSVELD

FIG 33. SOLE WITH STRAPS. PHOTO BY EVA IJSVELD

FIG 34. RECONSTRUCTION BY EVA IJSVELD OF LIMEBARK SHOES MAUR-SCHIFFLAENDE, SWISS. PHOTO BY EVA IJSVELD

FIG 35. PHOTO OF THE NET FROM ÖTZI MUSEUM WITH ADDED LINE BY EVA IJSVELD

FIG 36. BACKSIDE WITH LACING. PHOTO BY EVA IJSVELD

FIG 37. STARTING OF THE LACING. FOTO BY EVA IJSVELD

FIG 38. CLOSING WITH A LOOP DETAIL PHOTO 2 AND PHOTO BY EVA IJSVELD

FIG 39. THE LACING IN THE RECONSTRUCTION. PHOTO BY EVA IJSVELD

FIG 40. BOTH SHOES FINISHED. PHOTO BY EVA IJSVELD

FIG 41. BOTH SHOES SOLES WITH STRAPS. PHOTO BY EVA IJSVELD

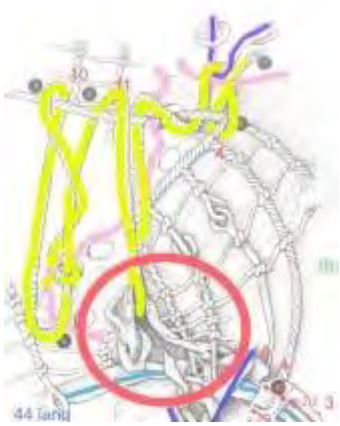

FIG 42. DETAIL FROM EGG AND SPINDLER (2009, FIG. 18). FILLED IN LINES BY EVA IJSVELD

FIG 43. THE OUTSIDE LEATHER STRAP OF COWHIDE. PHOTO BY EVA IJSVELD

FIG 44. TEST WITH LACING UNDER NEED THE LEATHER STRAPS. PHOTO EVA IJSVELD

FIG 45. PLACEMENT OF THE STRAPS FROM ABOVE. PHOTO BY EVA IJSVELD

FIG 46. SHOE WITH SIDE STRAPS. PHOTO BY EVA IJSVELD

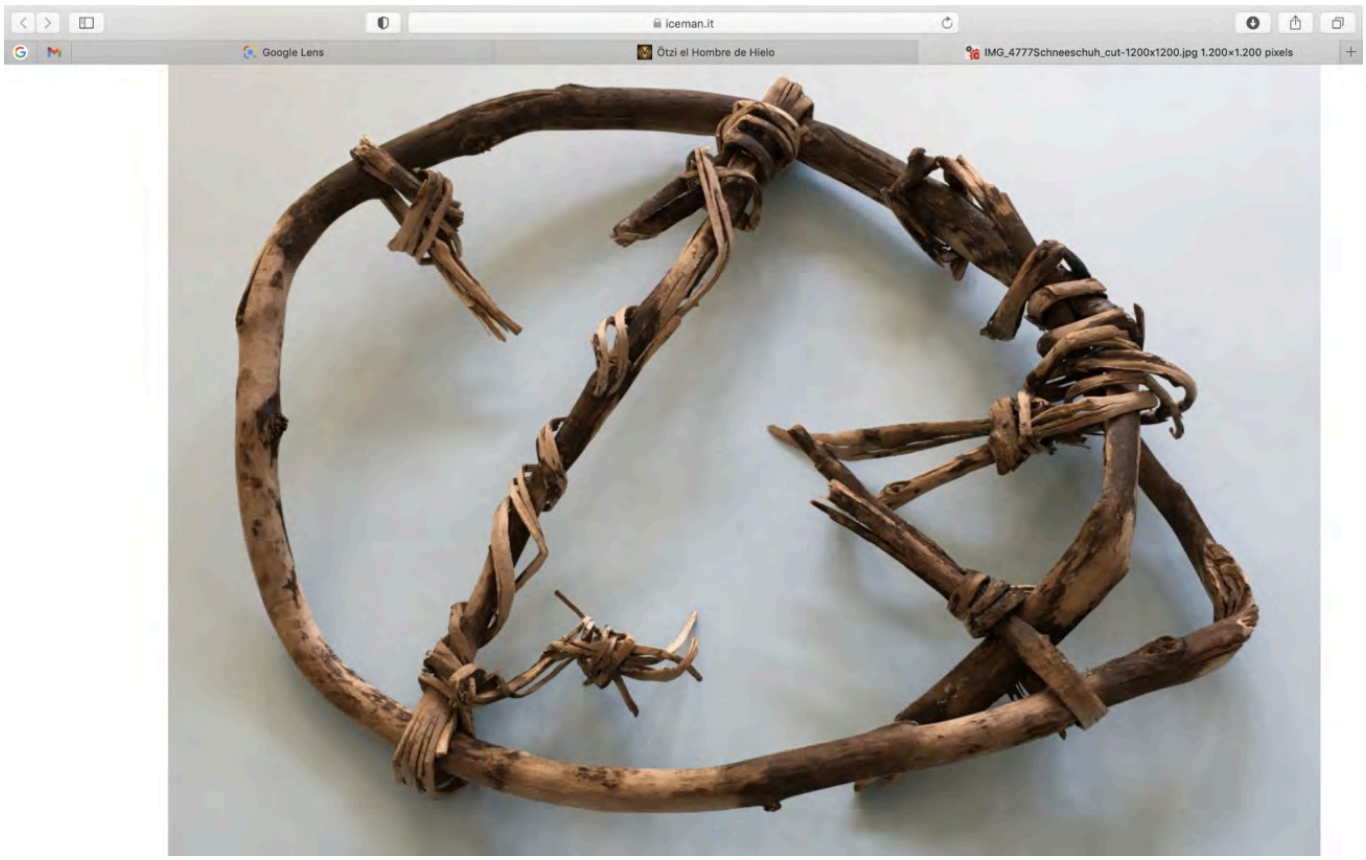

FIG 47. SNOWSHOE FROM GURGLER EISJOCH-PFOSSENTAL (3.800-3.700 V. CHR). PHOTO FROM WWW.ICEMAN.IT SOUTH TIROL MUSEUM OF ARCHEOLOGY.

FIG 48. FINISHED SHOES, PHOTO EVA IJSVELD

FIG 49. FLINTSTONE KNIFE USED FOR MAKING OF THE SHOES. PHOTO BY EVA IJSVELD

FIG 50. THE STEP-IN ROPE. PHOTO EVA IJSVELD

FIG 51. SHOES WORN WITH LEGGINGS TUCKED IN. PHOTO BY NIELS SCHERPENZEEL

FIG 52. SHOES WITH LEGGING FROM THE BACK, PHOTO BY NIELS SCHERPENZEEL