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A Bowstring in Ötzi's Quiver?

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Abstract

This paper tries to shed new light on the bowstring-hypothesis of the bark string found in Ötzi's quiver. Therefore, an experimental program was set up, starting with the realisation of a working replica. An evaluation was made of its mechanical properties as well on the level of the raw material as of the technical aspects of the string, followed by stretch and resistance tests, and shooting exercises. The confrontation of the results with archaeological and ethnographical data conducted us to a better understanding of its characteristics.

Introduction

When Ötzi's remains were discovered in 1991, the rough-out of a bow, made of yew, was found, among other objects, in the area of the mummy. Systematic excavation of the site also yielded a quiver of goatskin, which contained fourteen arrows, antler points, tendon and a wrapped string (Fig. 1).

The description of the string (Egg & Spindler 1992) notes that the raw material is bark fibre, initially of two, and then of three strands, twisted together in an S-pattern. Diameter varies from 2 mm to 6 mm. Because the string has not been unravelled, the actual length could only be speculated, but it is probably between 1.75 and 2 m (Fig. 2). The photographs and drawings do not give the impression that the string was irregular, so it is believed that those variations in thickness were the result of the fabrication technique. The 2 mm thickness related to the initial part of string, made by two strands, and increased to 6 mm with the addition of the third strand.

According to the classification of Gay (Lepers 1999), the string was classified as a *bitord* that changed into a *merlin*, because of the particularity that one end contains just two strands.

The hypothesis

Egg and Spindler (1992: 50) speculate whether this string could be Ötzi's bowstring. If so, it should be able to resist the tension of the bow when strung, and be able to hold an arrow nock of 4 mm. In 2004, the idea gained ground that experimental archaeology could do its bit towards an answer of this question (Casseyas 2004).

The experimental approach

Inevitably, first of all a working réplica had to be made. At the beginning of the summer, bark strips of young Lime *(Tilia cordata)* were soaked in water. Regular checking enabled us to determine that four weeks retting were enough to allow the bacteriological activity to separate the bast fibres from each other. After rinsing and drying, we had a stock of ribbons, between 1.5 and 2.5 cm wide and 2.5 m long.

The principle of twining (Lepers 1999) is to twist separately two or more strands of fibres once and in the same direction. Afterwards, each strand is crossed over its neighbour, but in the opposite direction. Then the twisting and crossing movement is repeated to continue the rope. Because of the analogy

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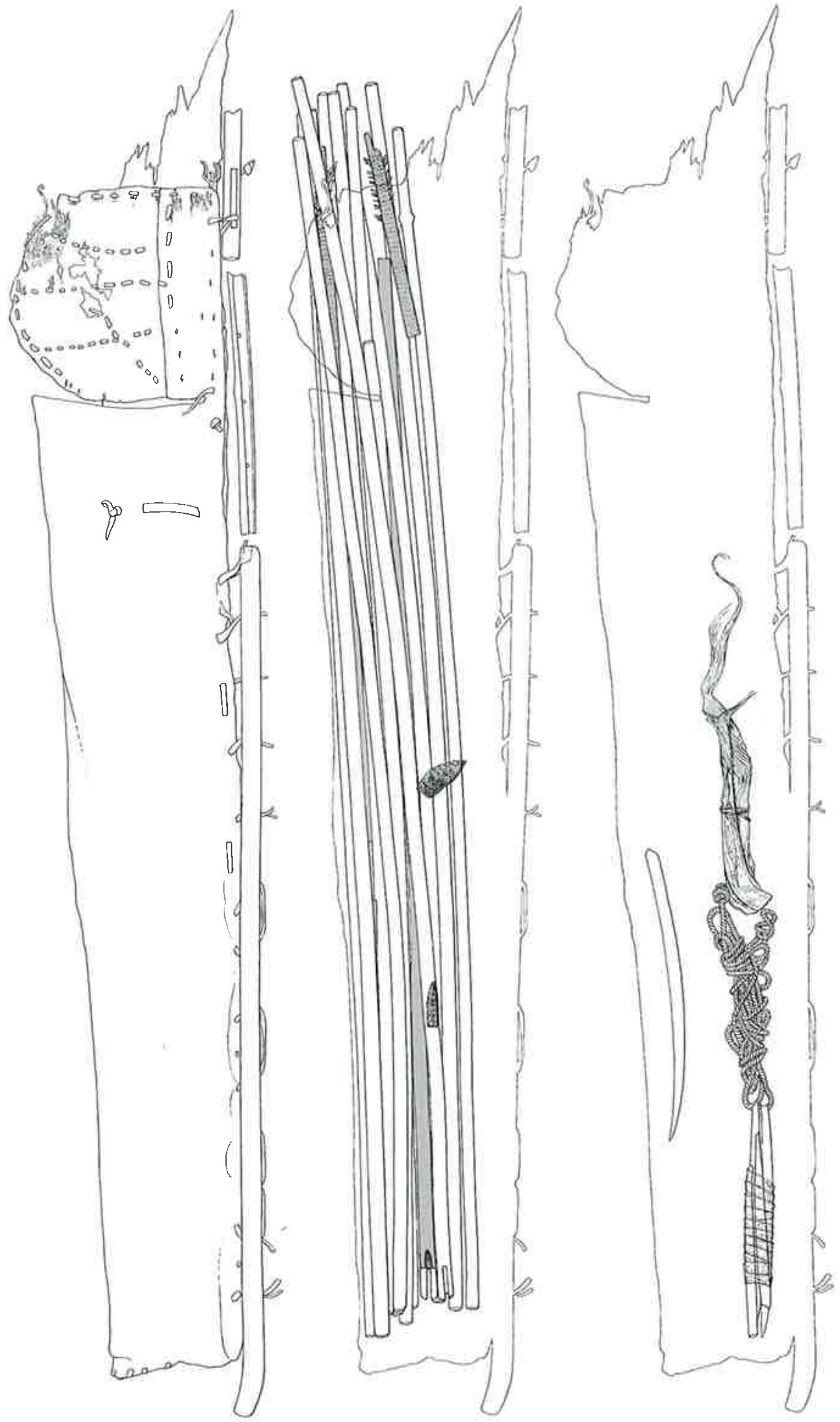

Fig. 1. Position of the string in the quiver. – © Egg & Spindler 1992: 45, fig. 8.

Fig. 2. The string. – © South Tyrol Museum of Archaeology.

between the orientation of the spiral line and the letter, we define "S" and "Z" ropes. An S rope, like the one found with Ötzi, means that the wreaths have been crossed over each other to the right.

It took exactly 31 minutes to create a two meter long string. To obtain this, we worked threads of exactly 218 cm, because the twining causes an 8 % loss from the raw material length. The string has a weight of 28 grams (431.2 grains). The threads are very regular: from the moment that we added the third strand, there was no need to add or to remove any material to keep the width of the string between 5 and 6 mm.

Table 1 combines technical data as proposed by Lepers (1999). The angular coefficient is based on the average length of the measurements on ten half spires of the helix divided by the half of the circumference of the string.

Table 1. Description of the string and the strands.

	string	strands
Average diameter	5.4 mm	3 mm
Number of spires	3	Inestimable: plant-fibres
Direction spiral line	S	Z
Angular coefficient	a = 14.2 / 8.4 = 1.67	a = 6.0 / 4.71 = 1.27

Fig. 3. The stretching machine. – Photo: C. Casseyas. ▷

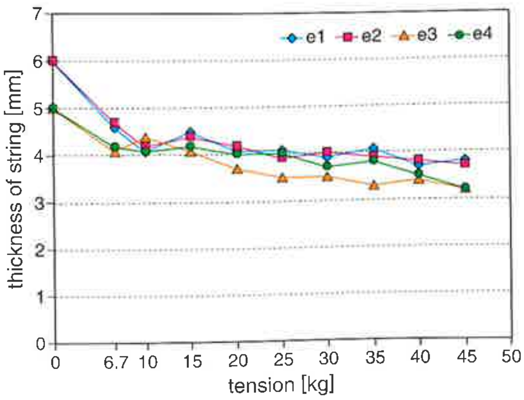

Fig. 4. Influence of the tension on the thickness of the string.

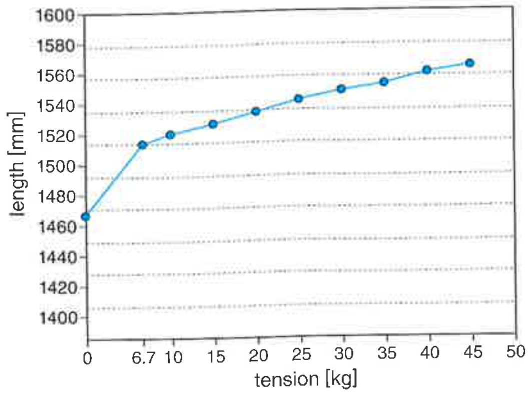

Fig. 5. Influence of the tension on the length of the string.

As noted above, the two principal questions of Egg and Spindler (1992: 50) were: is the string able to resist the tension of the bow when strung, and is the string able to hold an arrow nock of 4 mm?

In the state that the string was discovered, it was too thick to receive a nock. It is then important to determine whether the string retains its thickness of 6 mm under tension once fixed on the bow. To check this, the diameters of the experimental string were recorded while it was submitted to an increasing weight.

We improvised a "stretching machine" (Fig. 3). A double ladder was opened to keep a stick in a horizontal position at a certain height. One end of the experimental string was attached to the stick. A kettle was attached on the other end, and suspended 10 cm above the ground.

A meter stick was suspended parallel to the string. The string itself had 4 individual marks: two marks at five mm diameter, the other two at six mm diameter.

The initial weight of the kettle itself was 6.7 kg. By adding water, it was possible to increase the charge and thus the tension supported by the string in a quantifiable manner. The initial charge caused a sudden decrease of the diameter of the string. Under additional weight, this diminution continued, but less spectacularly (Fig. 4 and Table 2).

Once relieved of the kettle, the string regained some of its initial diameter, but not completely; nowhere could we measure more than 5 mm diameter.

This phenomenon was accompanied by a general stretch of the string (Table 2 and Fig. 5).

Using ten measurements, we then recalculated the angular coefficient, which (logically) had risen: a = 12.7 / 6.28 = 2.02

Aside from its stretch, the bowstring's resistance is also of crucial interest: actual bowyers and marksmen take into account that a good bowstring should preferably be four times stronger than the draw weight of the bow (Baker 1993). We attempted to determine the maximum tension that our string can support.

We returned to the stretching machine, but increased the load until we reached the breaking point of the string. The string was cut into five pieces so that the experiment could be repeated. To avoid friction, pieces of leather were rolled over the ladder stick and the kettle handle.

The pieces of the string broke when loaded with 57, 55, 73, 53, and 57 kg respectively. Therefore, the string would be adequate for a 13.25 kg (29 lbs) bow.

Table 2. Variation in thickness and length of the string under increasing tension.

charge [kg]	thickness [mm]				length [mm]
	e1	e2	e3	e4	
0	6.0	6.0	5.0	5.0	1476
6.7	4.6	4.7	4.1	4.2	1520
10	4.1	4.2	4.4	4.1	1526
15	4.5	4.4	4.1	4.2	1532
20	4.1	4.2	3.7	4.0	1539
25	4.1	3.9	3.5	4.0	1545
30	3.9	4.0	3.5	3.7	1551
35	4.1	3.9	3.3	3.8	1555
40	3.7	3.8	3.4	3.5	1562
45	3.8	3.7	3.2	3.2	1566

Discussion

Archaeological context

This chapter points to arguments either in favour of accepting the existence of a bowstring, or of doubting on it, even to believe in the existence of a replacement bowstring. Ötzi was obviously a serious archer, and his bow was part of his daily survival equipment. Because no bowstring was found on the bow itself, the only string found which could have been a bowstring is the one in the quiver.

However, the quiver was broken, and the bow and 12 arrows unfinished. Consequently, there is good reason to imagine that the real bowstring could also be missing. Furthermore, the string in the quiver does not have any loops or typical knots. Moreover, Ötzi also transported other objects that had nothing to do with archery.

On the other hand, even if the quiver contained more than just arrows, the tendons and points can be interpreted as a stock of replacement pieces for repairing or making arrows. If the string was found together with these objects, it is more plausibly a replacement piece than a used string.

The combination quiver-arrows-bow-string has also been found in Schnidejoch (Suter et al. 2005), but in this case it cannot be excluded that the string once was attached to the (finished) bow. As far as we know, no other sites yielded bows with a bowstring.

The choice of raw materials

In traditional archery, the best bowstrings are made of plant fibres. By "best" we do not mean "strongest". Bowstrings made of animal fibres, although very strong, have the disadvantage to be more elastic and partially absorb the energy of the bow. However, this material had been chosen for the Schnidejoch-string (Suter et al. 2005).

A first choice bowstring must be strong and not elastic. Among natural materials, vegetable fibres are preferable to animal ones because they are less elastic and do not absorb energy during the shot.

Ötzi, therefore, made a good decision by using a bowstring of plant fibres. However, in that category, there are also different qualities. The best quality is hemp *(Cannabis sativa)*. By choosing the best quality of plant fibres, it is possible to make a thinner string that is faster and transmits better bow energy into arrow speed. By choosing bast fibres, Ötzi had chosen low quality raw material.

The reason for Ötzi's choice is unknown. Baker (1993) enumerates bast fibres for making bowstrings, but does not specify which ones. We believe that among bast fibres, there must be different qualities. We have taken lime bast because it is most common in archaeological records. The tree must have been known by the Iceman because the retouching tool was made of that kind of wood. Ethnographical studies have demonstrated that the choice of raw material and the motivation can vary: gut, skin, tendon and silk bowstrings are all used. For instance, elastic silk strings are preferred for composite bows, because strength is the most important criterion for strings that are difficult to undo from their bow. Low quality bowstrings like Ötzi's are also used: Indian tribes of Brazil use palm fibres for the bowstrings for their longbows (Baker 1993), and take a second string as a spare when they go hunting because this weak string will quickly wear out and break.

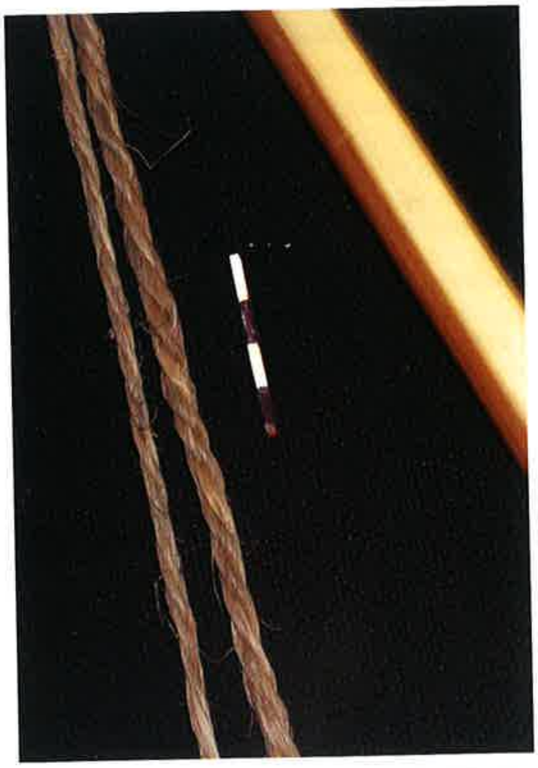

Fig. 6. The same string under tension and without. – Photo: R. Fontaine.

Fig. 7. Positioning the arrow nock without problems. – Photo: R. Fontaine.

Considering the time needed to ret bark and to twist a new bowstring, foreseeing a ready-made for a quick replacement of a worn or broken bowstring was just a tactical point of view of Ötzi. It must be noted that Ötzi's string has no loops and does not give the impression of being worn. Thus, it may have been his reserve string.

The technical aspects of the string

According to the Iceman's bow of 182.5 cm, and for allowing loops, the string must have been at least 195 cm, i. e. 160 cm plus 20 cm for the loop and 15 cm for a timber hitch. The estimated length of the string discovered in the quiver is, therefore, close to the one expected for the bowstring. Because of the unfinished state of the bow, it could also be that Ötzi intended to make conical nocks. This alternative demands coiling the ends to tie the bowstring, or fastening by passing the string ends through the hole of a perforated disc, which can be put over the conical nocks. In the first case, the string needs to be longer, in the other case, it can be shorter.

Low quality fibres require thicker strings, but thicker strings are weaker, because the tension on the outer fibres is more important than the one on the inner (Baker 1993). The solution, but not found on the Ötzi string, rests in spreading the tension by using the *aussière* technique (Lepers 1999): instead of strands of fibres, rope yarns (sub-plies) are twisted and crossed into a string.

Ötzi's string had to be thick, even if this would reduce arrow speed. The string seemed also to be too thick for the nock, until the string was put on a bow and stretched. Once the string was stretched, there was a dramatic reduction in diameter, and the arrow nock could easily be fitted to it (Figs. 6, 7).

Keeping in mind that the string can break starting from 53 kg (116 lbs), the strength of the bow should not exceed 13.25 kg (29 lbs) to be adequate. Ötzi's bow was unfinished so we cannot measure its draw weight with certainty. Our reconstruction of the bow (with sinew backing) in yew wood cut in 1999 followed the measurements of the original: 182.5 cm long, with a width of 3.6 cm, and maximum thickness of 3.2 cm). Unable to pull the string far enough on something which looked more like a pole than like a

Fig. 9. Condition of the string after 200 shots. – Photo: R. Fontaine.

Fig. 8. Experimental shooting with the bast bowstring. – Photo: R. Fontaine.

bow, we used once again the "stretching machine" but this time, we hung the kettle on the string of the drawn bow. Baugh et al. (2006) calculated the Iceman's bow draw weight by computer modelling. We also found a reconstruction by Paulsen in the literature (Fleckinger 2005: 79). We have summarized the results in Table 3.

Our reconstruction can be criticized because of the sinew backing, but its results are closer to the theoretical model of Baugh et al. (2006) than to Paulsen's (Fleckinger 2005). Ötzi had an unfinished bow, confirmed by the rough surface with the tool marks, and certainly had the intention to make his bow slimmer.

According to Junkmanns (2001), Neolithic bows for adults vary from 16 to 32 kg (35–70 lbs). The conclusion, therefore, is that a mediaeval archer or a modern target archer would not recommend a string like Ötzi's.

Even if it is not an ideal string, how far can it be used? In a fit of rashness, we tested another replica of the bowstring on a 55 lbs bow, but it broke before the first arrow was shot. We made a third string that we prudently tried on a 47 lbs bow. One hundred arrows were shot. We felt that the bow was less tense than with the classical flax string we used on it. In our impetuosity, we put the string again on the 55 lbs bow and this time we succeeded shooting 100 arrows (Fig. 8). We observed, however, that the friction by the nocks of the arrow and the bow had worn the string (Fig. 9).

Table 3. Comparison between three reconstructions of Ötzi's bow.

Author	Casseyas	Baugh et al.	Paulsen
Draw length	70 cm (27.5 in)	71.1 cm (28 in)	72 cm (28 in)
Draw weight	90 kg (198 lbs)	75.7 kg (166.9 lbs)	28 kg (61 lbs)

Conclusion

This experiment addressed the questions posed by Egg and Spindler (1992): the string is long enough to be used as a bowstring and would take the tension on a Neolithic bow as well as accept an arrow nock of 4 mm. The archaeological context adds arguments in favour of a bowstring in reserve. The particular choice of raw material may result in an inferior bowstring, both weak and slow, and not the ideal of a modern archer but ethnological parallels demonstrate that it should not be rejected as the string of a primitive bow.

Acknowledgements

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