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Western-european prehistoric Wide Bows, analysis & evolution

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The bow is the oldest and most complex human-made tool still in use today. It stores muscle energy and then transmits it back to the arrow, propelling it toward its target with great power and precision. This 'propulsive-spear' combination appeared in very ancient times, generally considered to be in the late Paleolithic period, and is not now in widespread use, except for recreational purposes.

Alongside bows made of more modern composite materials the longbow (selfbow or laminated) is currently widely used in Western Europe, for traditional and instinctive archery. There was not however a single form for these early bows and they were made of a variety of woods. The yew bow did however become widespread in most of western Europe from the Neolithic period, but not always in the same form. However, yew was not the only wood used as evidenced by the elm bows from Holmegaard (Denmark).

Elm is a medium-strength wood (not as weak as pine, but not as resistant as oak or yew), requiring the distribution of tensile forces (extension / compression) over a large frontal area to avoid breaking. Of course, the Holmegaard bow is the oldest preserved wide-limbed bow, but it is not the oldest bow, and comparing all wide bows to this one would be an erroneous simplification. This is a very distinct wide bow model, but other models have also existed and not all of them were elm, nor Danish.

This analysis of West European bows from prehistoric times will be done in two parts. It is first necessary to establish a frame of reference, a basis of analysis, a common vocabulary in order to describe the bows and the families. Then we will follow the chronological evolution of the bows found during excavations.

Bow's description

In this first part, we will try to establish a common nomenclature that can be used to analyse bows and classify them by families in order to follow their evolution. From then on, an attempt will be made to describe their facial profile, their lateral profile, the manufacture of the handle, the cross section, and the ends of the limbs.

In the second part, we will deal with the families of wide prehistoric bows and the types of wood used. As a separate study it would be interesting to compare the prime use of these woods with the climatic displacement of forests after the last glaciation.

Bow's lateral profile

There are many different profiles in use around the world. Each region has its characteristic profiles, summarized globally in Figure 1.

In Western Europe, this is mainly the *'straight' profile (P1)*. If the unbended bow is visibly not completely 'straight', we must ask ourselves if the 'curvature' is due to a later deformation resulting from the conditions of preservation for hundreds of years. Or maybe it is simply due to the original shape of the tree trunk or branch, or is it the result of regular usage by the archer i.e. what is described by modern archers as 'string-follow'. If the bow stave was originally curved, a 'straight' bow will naturally follow that curve. Of course, the objective is to have a really straight bow, a wooden bow naturally 'deflexed' or 'decurved' will be lacking in energy restitution, and will therefore be less efficient, whereas 'recurved' or 'reflexed' shapes will give an increase both in power of the limbs and in the effort needed to draw them.

Bows facial shapes

The vast majority of West European bows being 'straight' bows (lateral profile P1), the most visible differences will therefore be in the facial profile. We can already make a division here: is the handle an area within the continuity of the limbs or is it discontinuous? In other words, is the bow narrowed at the centre? Does the width of the bow allow the grip? Or is the bow wide? Is it too wide to allow the grip, and does it therefore have to be narrowed to make the handle? Seen from the front, the distinction is easy to recognize. And in each of these two categories, we can also make distinctions on the shape of the edges of the bow limbs (see figure 2).

For continuous bows, we generally have two categories:

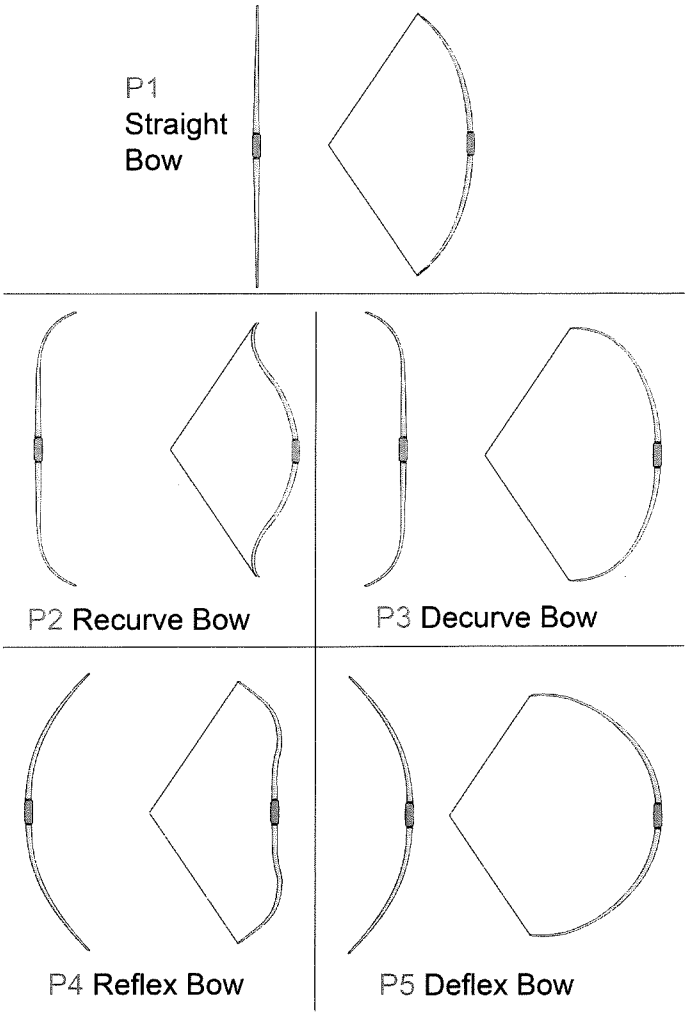


Fig. 1. Bow's lateral profiles.

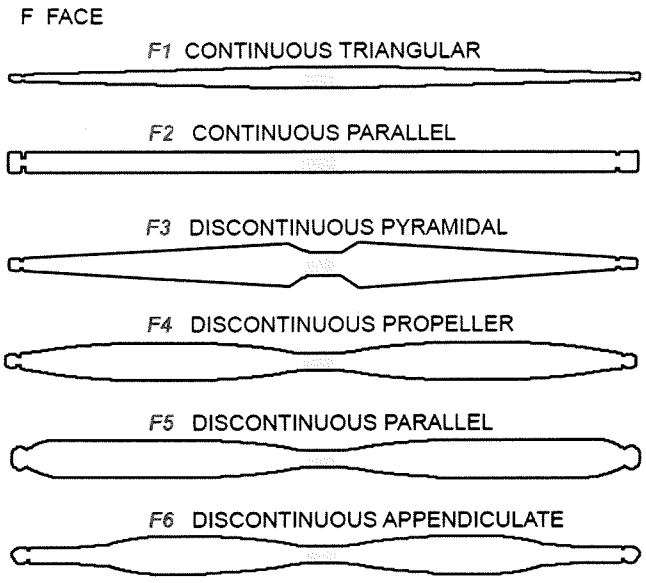


Fig. 2. Bow's facial shapes.

The *triangular continuous bow (F1)* has its greatest width at the level of the handle and its limbs are narrowed towards the ends only. This is of course the best known. Most current traditional longbows fall into this category, as do those from the 16th century wreck of the *Mary Rose* (Great Britain).

The *parallel continuous bow (F2)* sees virtually no reduction in its width between the handle and its ends. We know few examples of this type of bow in West-Europe, but we can cite the Pineuilh bow (France).

For discontinuous bows, the grip of which has been narrowed in relation to the width of the limbs, we can also distinguish several facial shapes of the limbs.

The *pyramidal discontinuous bow (F3)* is also the best known here. Its greatest width is located closest to the handle. The grip is neatly cut out at the base of the limbs, in the centre of the bow, where the thickness (between belly and back)has been kept greater to prevent breakage. The limbs narrow to the end only. The Holmegaard bows (Denmark) fall into this category.

The *propeller discontinuous bow (F4)* shows more rounded limbs. The maximum width is rather in the middle of the limbs. And the limbs become narrower on both sides, towards the handle as well as towards the end. It's not about making the bow and then excavating the grip, but planning the grip from the start. The manufacture of this type of bow is therefore very different from the pyramidal bow. The bows of Meare Heath (Great Britain), and Muldbjerg (Denmark) are good examples.

The *parallel discontinuous bow (F5)* is a variation of the F4. If the branch or the starting stave is thin enough, it will be easier to keep the width intact over most of the length of the limbs, by refining only the ends and the handle, always gently, but over a shorter length. The distinction between F4 and F5 will sometimes be very fine, so these two groups will be considered here together. In this sub-family, for example, we have the bow of Ronaes Skov 1 (Denmark).

The *appendiculate discontinuous bow (F6)* is the strangest and most distinct one. Its central part is like the propeller bow (F4), but in the middle of its limbs (between 50% and 65% away from the handle), a shoulder of about ten centimetres appears, narrowing the limb and completely changing the section of the bow. The outer part of the limb is therefore refined and more oval. These bows can be found exclusively in a specific area around Denmark (Mollegabet, Tybrind Vig Type 1), and in a specific period.

Bow handle making

If we consider strictly the historical handle (if it is preserved), we can distinguish four aspects, two of which are now obvious:

The *continuous handle (H1)* has the same width as the limbs (for the bows F1-F2).

The *thinned handle (H2)* is thinner than the width of the limbs (for the bows F3-F6).

But we can also see that some handles are *extra thick* (between back and belly) *(H3)* compared to the thickness of the limbs. In the case of those bows with (laterally) thinned handles (H2), this is necessary to avoid an area of weakness at the level of the handle due to a lack of wood, and therefore to avoid breaking. But we can also find extra thick handles for continuous handles (H1) and bows (F1 like Lupfen / Oberflacht, Germany, or F2 like Pineuilh, France). The extra thick handles are therefore not uniquely related to the narrowed handles (H2).

Finally, it be noted that the *comfort handles (H4)*, which means having a specific arrangement for the comfort of the hand gripping the wood, such as winding of leather, or fabric, did not appear until very late. They were probably primarily used on recreational bows from the late middle ages,they are certainly seen in 17th century English portraits, and in England were universal in the 18th century.

I will only mention in passing the *ergonomic handles* (H5) of modern bows.

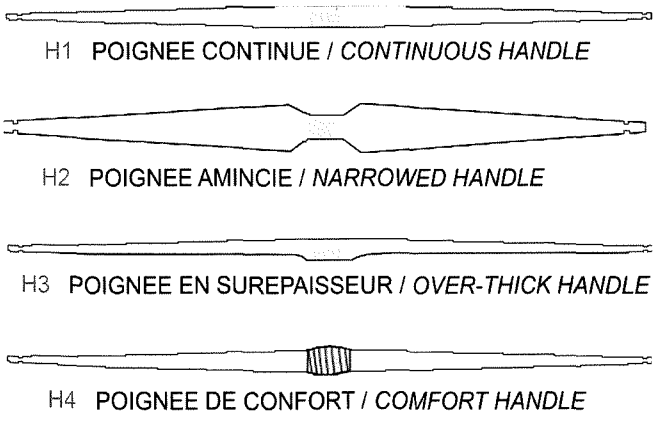


Fig. 3. Bow's handle making.

Limbs and handles, wood cross-section

This aspect is the one that shows the greatest variety, and which teaches us the most about the technique of bow making and its dynamics, but is also the most difficult to analyse. This would require a cross section of the limbs, but of course damaging historical artefacts is out of the question. So, we will analyse them from the outside, as well as using the natural breaks in the artefacts, and what we can see of the yearly wood growth rings.

Here we must first ask ourselves a few simple questions:

What was the original diameter of the wood and is the central ring present or not? So, does the wood come from a large trunk split into 2 or 4 billets (large diameter and central ring often absent), or a thin branch worked alone (smaller diameter and central ring often present)?

And most importantly: has the outer ring, just under the bark, been preserved? This point is indeed crucial. In a bow, there is a side which is subject to extension forces (back of the bow; external side facing the target) and a side subject to compressive forces (belly of the bow; internal side, facing the archer). The back is the most critical side and presents the most risk of rupture. Therefore, the back of the bow must have the wood outer ring preserved, without any defect. If the outer ring does not seem to have been used on the back, one wonders for what reasons.

There are other questions that may arise before looking at the cross section itself. Does the wood show knots? How were they treated? Have they been removed cleanly by following the grain of the wood? Have they been left in place (creating a heavy, non-dynamic point), with wood kept surrounding the knot to strengthen the bow there? This can teach us a lot about the skill and experience of the bowyer.

Let us now analyse the possible profiles, considering the most probable case: the outer ring is preserved and used at the back of the bow. If this is not the case, we can often get closer to one of the sections defined here, without too much difficulty, by specifying that the outer ring is broken. Figure 4 shows a great diversity of sections, which can be used to analyse all the western European bows between the Palaeolithic and the 19th century. Of course, all these sections will not be found in the prehistorical bows. And some sections (S2e, S4b, S54g, some S5e and S5f) will mainly be sections used for handles.

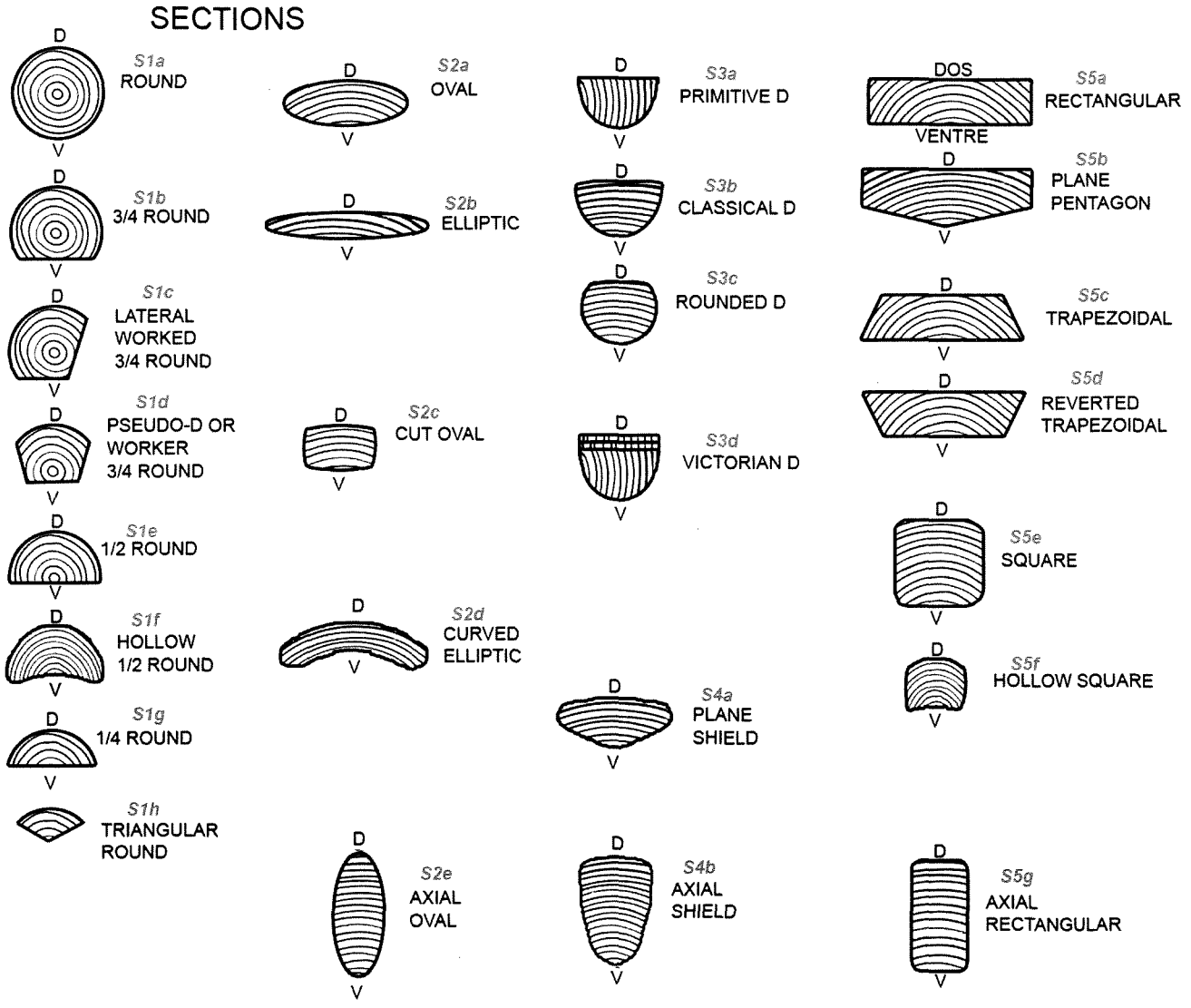


Fig. 4. Wood cross-sections.

In the existing literature, many writers (historians or not) often mention the famous 'D-section' but in rather imprecise way. Depending on the original diameter of the trunk, the wood will be worked differently and show very different 'D-sections'. A small diameter trunk will keep an outer ring (back) strongly rounded and will be worked flat on a small width. We will thus obtain sections S1. But a large diameter trunk, split into several billets, will also keep the outer ring intact on the back. This will have a larger radius and therefore a much flatter external curvature. The wood will therefore be worked on the belly over a larger surface and it will be easier to work it (with a scraper, or with a drawknife, for example) in rounding, to reduce the work surface. The rounding will therefore be located here, not on the back but on the belly of the bow (sections S3). In these two cases we will obtain a "D-section" (flat on one side and rounded on the other), but of different dynamic operation and totally opposite manufacture.

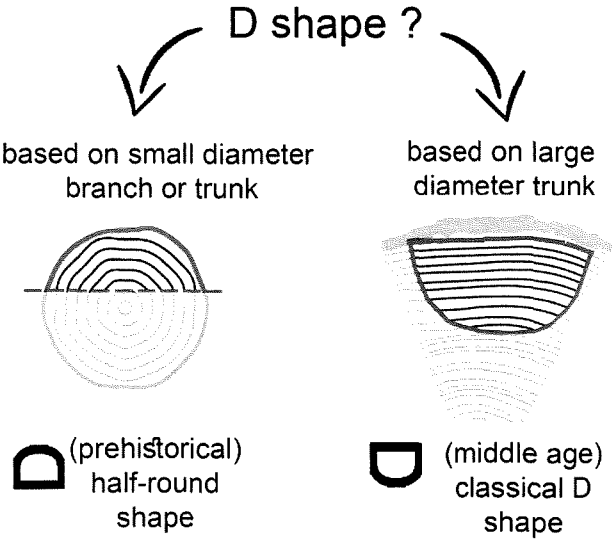


Fig. 5. D-shape issue.

This 'D-shape' issue and the confusion that arises probably stems from early 20th century writers, who referred to present-day recreational English longbows made from laminations, therefore completely different in manufacture. These are composed of an assembly of two or three layers of different wood (see section S3d), and which cannot serve as a point of comparison for historical bows before the 17th century. Here, in fact, the rings are perpendicular to the axis of the bow. The wood coming from pre-cut lamina, it is impossible to preserve the outer ring on the back. Therefore, to avoid breaking the bow limbs, another way of working was used, perpendicular to the rings.

A word also about the 'primitive' section S3a. Paul Comstock (American bow builder) explained that the primitive Mannheim and Stellmoor pine bows (c. 14,000-10,000 BC) were made perpendicular to the rings of the wood. This can be explained as a way to avoid breaking the pine wood, which is very weak, but it is impossible to verify, since two of the three artefacts disappeared during the bombing of Germany in WWII. The Mannheim bow was closer to the S1c lateral worked ¾ rounded section, and the Stellmoor bow was clearly rounded (S1a) in one artefact but too fragmented to be sure in the other. While his interpretation is not impossible, he probably based it on the Native American making of bows in the 19th century, also of pine wood but with wide, flat limbs. This information (and this section) is not really relevant here, unless other early bows are discovered made from pine, that are in sufficiently good condition to be properly analysed so as to accurately determine the back of the bow.

The section factor (Fs) and the width factor (Fw)

Some researchers have tried to define groups of bows according to the different widths found (considering full bows). But for a pyramidal bow (for example), considering that the overall profile remains the same, in the same proportions, it becomes obvious that if we make a bow of great length, its width will also be increased. Does that make it a different bow? Not really, it could just be a bow for a different sized archer, for example. Likewise, we can try to make families based on different thicknesses. But here too, a larger width will bring a greater thickness. It can also be explained by a desire to obtain a more or a less powerful bow. Indeed, while the width often determines the solidity of the bow, its thickness determines the strength of the bow. Making two bows of identical shapes but of different strength (thicknesses) does not make them bows of different families. If you want to compare bow measurements, which is always useful, then you must use ratios. Compare proportions, not just measurements. Two ratios can be proposed here.

The *section factor (Fs)* is defined as the width divided by the thickness. If Fs> 1.7, then we can consider that we have a bow with so-called 'wide' limbs.

The *width factor (Fw)* is defined as the width divided by the length (actual or estimated in the case of a bow fragment). Note that many wide bows will have a value of Fw between 2.0 and 2.5%. Sometimes for wide bows made from thin branches (for example), the values will drop between 1.7 and 1.9%; and rarely, for particularly wide bows, will have a Fw value greater than 3%.

We also could compare the thickness and the length of the bow. For the same length, the thickness will be indicative of the strength of the archer. We could suggest that a weaker bow might be used by a female or a young man, or by a less trained archer. But this speculation is about the possible user, rather than about bow analysis, and therefore will not be considered here.

Of course, these measurements are estimates which depend very much on the state of conservation of the artefacts. They can only guide us in determining the bows particular family, whereas the facial and lateral profiles, as well as the manufacture of the handles, will be more determining.

Prehistoric wide bow evolution

Primitive pine bows

It is estimated that the bow appeared in Europe during the last phase of the last great ice age (48,000 BC). If we find knapped stone points from this period that are likely to be arrowheads, but no ancient bow of this period has come down to us. The wood fragments of the supposed bows of Stellmoor and Mannheim (Germany) date from 14,000/ 10,000 BC. And are made of pine.

It is indeed quite logical to consider that the first bows were made of an easy-to-find wood. As temperatures warmed at the end of the Glaciation, the pine forests must have been among the first to move north across the continent.

What shape should these bows have? Were they wide bows? The fragments of Stellmoor and Mannheim cannot tell us that. Pine is a weak and soft wood. It can be worked with rudimentary stone or bone tools. These bows probably did not exceed 150cm in length and made from worked branches rather than split trunks. It is also difficult to imagine that these bows could have been perfectly tillered, because of the quality of the wood, the nature of the tools available, and by the rudimentary knowledge of bow making at this early period of their development. They are likely to have been short, untillered

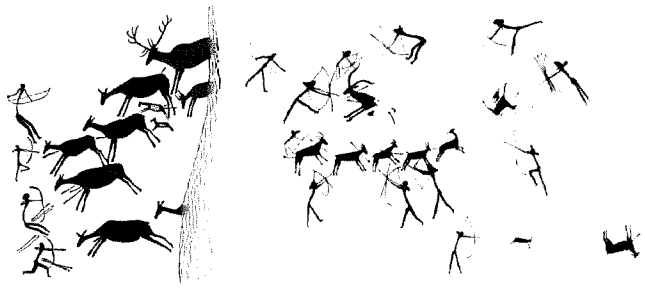


Fig. 6. Spain cave paintings (Valtorta and Cueva de la Arana).

bows with a finite lifespan but it is impossible to say more until we find a specimen that can be fully analysed, which is very unlikely.

However, Spanish cave paintings do show us this type of bow. If they are not very detailed, we can see bows a little smaller than the archers, and several of which show a 'hinge', an angle of curvature specific to badly tillered bows, whose limbs have a zone of weakness. These cave paintings date from 7000 to 3000 BC. Some of them must therefore show the primitive bows (in pine), others already the first bows in yew.

The forests change

With the disappearance of the glaciers (after 20,000BC), the forests move northwards, at different speeds depending on the types of wood. So, it seems that the hazel tree followed the pine. Then came the elm, the oak and the ash. The yew did not follow until about 1,000 years later. This requires a more complete study, but elm arrived in Scandinavia between 8000BC and 7000BC. The yew came to Spain around 5400BC, crossed the Alps around 5000BC, and did not arrive in Scandinavia until around 4500BC.

From a bow making perspective, then we have two new starting points. The making of elm bows in the southern Baltic area, and the making of yew bows in Spain. Does this mean that elm was not used in Europe before that? If we consider the time of the forest's move, elm would have appeared in Europe around 9000BC. The field of hypotheses is vast, but in the absence of artefacts from excavation, it is impossible to say with any certainty.

We therefore have two starting points. Yew bows, which will spread to Europe during the Neolithic, seem to appear in 5400BC in Spain (Banyoles). We will not discuss these bows very much here. The elm bows, of characteristic wide section, south of the Baltic, around 7700BC. The best known of these is the Holmegaard bow, but it is far from the only one.

The pyramidal bows

Elm is a wood of medium consistency. It is therefore normal that working with it required distributing the forces of extension and compression over a large area. This knowledge may have been inherited from the (even weaker) pine bows, but we cannot be certain. We therefore have the supposed appearance of wide limbed bows at the end of the Paleolithic, so wide at their limb base that the centre of the bow is too wide to hold in your hand. It is therefore necessary to excavate the handle laterally leaving a good thickness of wood in the centre, between belly and back, to prevent a lack of wood resulting in the breaking of the bow at the handle.

The elm bows from Holmegaard (Denmark) are magnificent examples of the pyramid bow. It is dated 6500BD. But it is obvious, when you look at it, that this bow is not a rough and hasty production. It is a well-finished, well-crafted bow, the grip of which was provided for in advance. It shows great skill and great care in manufacturing. There is no doubt that this bow is already the heir of a certain body of knowledge.

Table 1 Pyramidal bows

Bow (Location, date)	Info	wood	Real length	Estimated length	width	depth	Fs	Fw	Profile	Face	Handle	handle section	limbs section	End of limbs section	Outer ring preserved
Bolkow B/2010 (Pol, -7650/-7450)	Fragment	Elm	62	156	4,2	1,7	2,5	2,7%	P1	F3	/	/	S1g	S1g	Yes
Bolkow B/2016 (Pol, -7450/-7050)	Fragment	Elm	70	160	4,5	1,8	2,5	2,8%	P1	F3	H2/H3	S5e	S2a	S2a	?
Bolkow B/2012E (Pol, -7450/-7050)	Fragment	Elm	56	166	3,1	1,6	1,9	1,9%	P1	F4 ?	H3	S1b	S1e	S1g	Yes
Bolkow B/2011S (Pol, -7450/-7050)	Fragment	Elm	42	/	2,8	1,6	1,8	?	P1	?	/	/	S1e	S1g	?
Bolkow B/2013E/1 (Pol, -7050/-6550)	Fragment	Ash	99	160	4	2,2	1,8	2,5%	P1	?	/	/	S2a	S2a	/
Bolkow B/2013E/2 (Pol, -7050/-6550)	Fragment	Ash	106	162	3,5	2,5	1,4	2,2%	P1	?	/	/	S1e	S1e	/
Ulkestrup Lyng II (DK, -7050/-6550)	Complete	Elm	40	?	?	?	?	?	P1	F3	H2/H3	?	S2b	S2b	?
Holmegaard (Dk, -6500)	Complete	Elm	153	/	4,4	2,2	2,0	2,9%	P1	F3	H2/H3	S5e	S1g	S1g	Yes
Holmegaard (Dk, -6500)	Complete	Elm	90,5	168-178	6	2,1	2,9	3,4%	P1	F3	H2/H3	S5e	S1g	S1g	Yes
Blak (Dk, -6000/-5000)	Complete	Elm	?	150	?	?	?	?	P1	F3	H2/H3	S5e	S1g	S1g	?

Note about locations: Dk = Denmark, G = Germany, Hol = Holland, It = Italy, Nor = Norge, Pol = Poland, S= Switzerland, Sw = Sweden, UK = United Kingdom

This is confirmed by the recent discovery of two elm pyramidal bows in Bolkow (B/2010 and B/2016, Poland, Szczecin, Baltic coast). Dated to 7700/7000 BC, they prove that this type of bow already existed for at least 1000 years before Holmegaard. They have oval sections on the limbs and the B/2016 is almost square at the handle. They are accompanied by 3 fragments (B/2011S, B/2013E/1, B/2013E/2) too small to analyse the shape of the bow, although the wide bow shape is almost certain. One of these fragments is in elm, the other two in ash. Another elm bow (B/2012E) has also been found but requires more careful analysis. Indeed, if it is a wide bow, the grip is not differentiated in the width of the limbs, but it is very thick. It is a bow made from a fairly thin branch of tree it is too insubstantial to achieve a large width enabling reworking of the handle. This bow is of half-round section at the limbs and round at the handle where the branch section is practically intact.

The bows of Ulkestrup Lyng II and Blak (Denmark) are also examples of pyramidal bows, dating from 7000 to 5000BC.

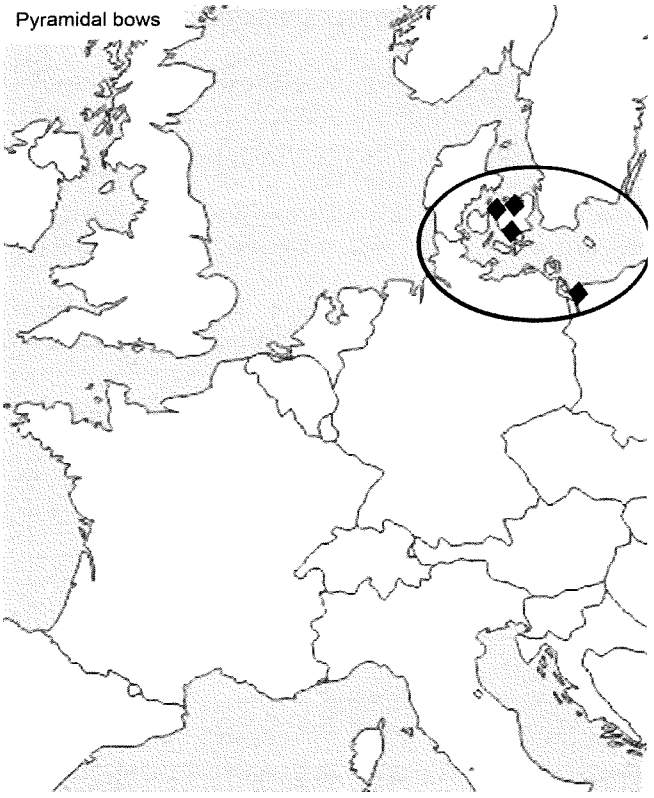


Fig. 7. Map of pyramidal bows.

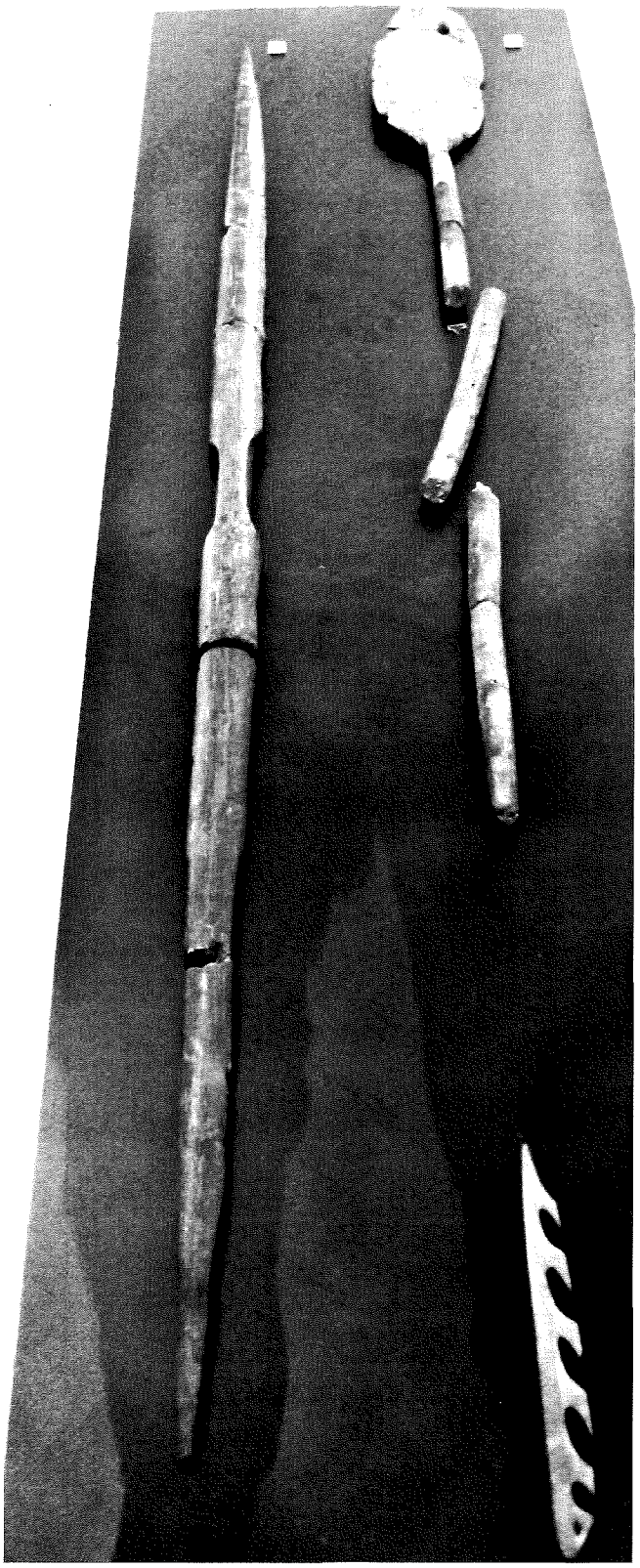


Fig. 8. Picture of Holmegaard bow, Danish National Museum (photo B.Detienne).

Bow evolution during Danish Ertebolle culture

What was the geographic extent of the use of the pyramidal bow? Over which period has it been used? It's very difficult to say without other artefacts from the past. But we can see a twin evolution of this model around 5300 BC. During this period, the Ertebolle culture (5300/3900BC) appeared in Denmark and gradually spread along the Baltic Sea in northern Germany. The appearance of this culture coincides with the appearance of two new bows models, still mostly elm, in this region: the propeller and appendiculate bows. These two types of bows appear in the same period, the older of the two models are discovered at Mollegabet, and are dated to 5400BC, but the propeller model had a wider lifespan and distribution.

Of course, within these two families of bows (propeller and appendiculate), we can define subfamilies, based on the sections of the bows which show slight differences. The inner face of the limbs (belly) seems to have been worked slightly differently for some bows (concave, convex, flat), but it is also possible that this work was simply a choice of the bowyer depending on the starting material, and the tools at his disposal. I omit the details of the subfamilies here, as the objective of this article is to take a general overview.

The oldest propeller bow ever found is probably the Mollegabet children's bow, in cornel (dogwood). It dates from the very beginnings of Ertebolle culture. But the two bows of Agerod V (Sweden), in elm and rowan, might also claim this seniority.

On the Danish sites, one can list the bows and elm fragments of Ringkloster 1 (5400/4700BC), of Tybrind Vig (two bows of type 2 and type 4, as well as probably 7 less identifiable fragments, 5300/4000BC), Smakkerup Huse (4800/3900BC), Ronaes Skov (3 bows, 4300/4100BC and the potential Brabrand ash bow (4600/3200BC). To this can be added the two elm bows from Timmendorf-Nordmole 1 (4500/4100BC) in northern Germany.

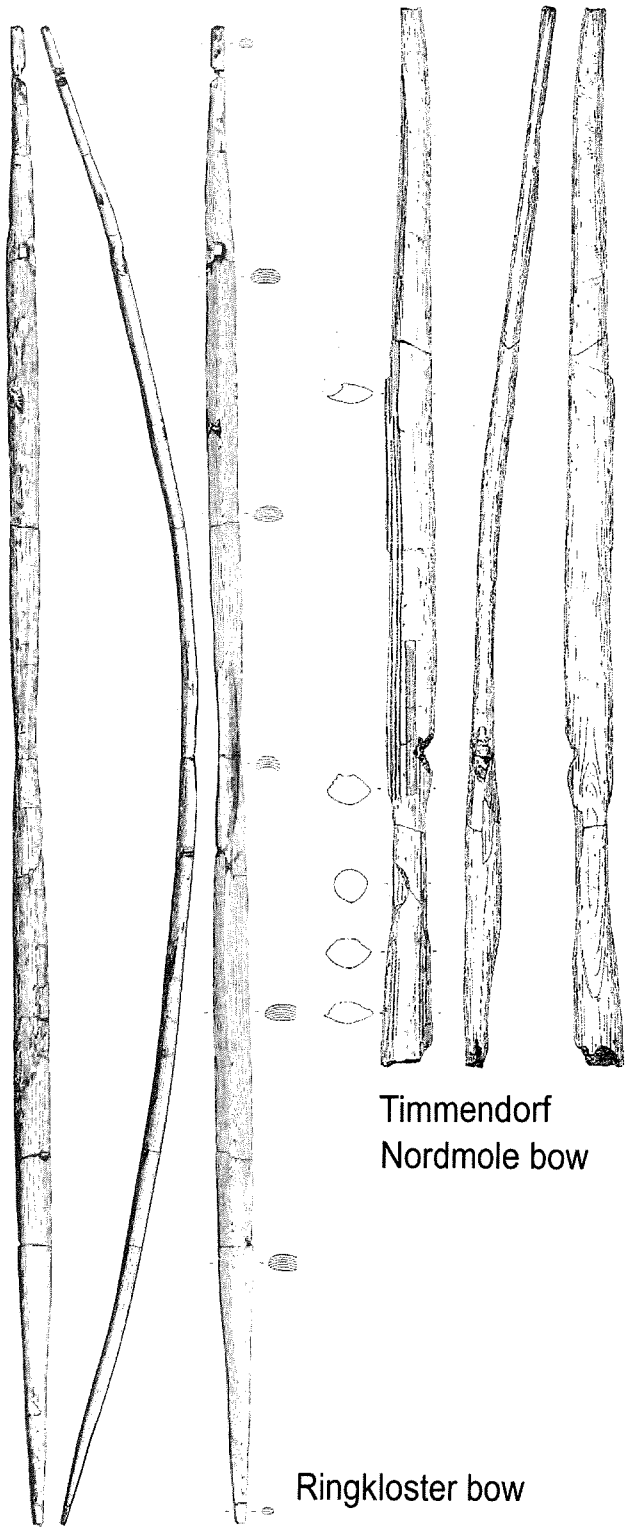
The bows of Neustadt (elm, 5100/4100BC, north Germany), Timmendorf-Nordmole III (ash, 4500/4100BC, north Germany), Agernaes (elm, 4300/4100BC, Denmark), and Rosenhof (elm, 4050/3150, Norway), are probably also part of this familly. Which shows the diffusion of this bow around the Danish peninsula.

This bow family remained in use on the Danish peninsula long after the disappearance of the Ertebolle culture (3900BC), as evidenced by the yew bow of Forstermoor Sartrup (3000/2750, northern Germany) and the elm bow of Muldbjerg (2900/2700, Denmark). As we will see a little further on, propeller bows will also be widely used in Europe.

Table 2 Propeller "Ertebolle" bows

Bow (Location, date)	Info	wood	Real length	Estimated length	width	depth	Fs	Fw	Profile	Face	Handle	handle section	limbs section	End of limbs section	Outer ring preserved
Mollegabet mini (Dk, -5400)	Fragment	Dogwood	83	86	?	?	?	?	P1	F4	H2/H3	?	?	?	Yes
Agerod V (Sw, -5760/-5430)	Fragment	Mountain ash	61,5	75	1,3	1	1,3	1,7%	P1	F4	?	S5g	S1e	?	?
Agerod V (Sw, -5300)	Complete	Elm	170	/	3,2	1,9	1,7	1,9%	P1	F4	?	?	S1e	?	?
Ringkloster 1 (Dk, -5400/-4700)	Complete	Elm	154	/	3,4	1,65	2,1	2,2%	P1	F4	H2/H3	S1a	S2a	S2a	?
Tybrind Vig - Type II (Dk, -5300/-4000)	Fragment	Elm	103	153	3,5	2	1,8	2,3%	P1	F4	H2/H3	S5e	S1e	?	Yes
Tybrind Vig - Type IV (Dk, -5300/-4000)	Complete	Elm	167	/	3,8	2	1,9	2,3%	P1	F4	H2/H3	S5e	S1e	S1g	Yes
Smakkerup Huse 1 (Dk, -4800/-3900)	Fragment	Elm	19	/	4,5	2,1	2,1	?	P1?	F4?	/	/	/	S2a	/
Ronaes Skov 1 (Dk, -4300/-4100)	Fragment	Elm	116,2	156,5	3,6	2	1,8	2,3%	P1	F5?	H2/H3	S2a	S1g	S1g	No
Ronaes Skov 2 (Dk, -4300/-4100)	Fragment	Elm	82	/	3,8	2,2	1,7	4,6%	P1	F4	H2/H3	S3e	S1g	/	No
Ronaes Skov 3 (Dk, -4300/-4100)	Fragment	Elm	7,3	/	2,6	1,5	1,7	?	P1	F4	/	/	S1g	/	No
Brabrand (Dk, -4600/-3200)	Fragment	Ash	60,5	/	3,5	1,8	1,9	?	P1	F4	H2/H3	?	S1g	S1g	?
Timmendorf-Nordmole I (G, -4500/-4100)	Fragment	Elm	102	160	3,8	1,6	2,4	2,4%	P1	F4	H2/H3	S3e	S1g	/	?
Neustadt LA156 (G, -4500/-4100)	Fragment	Elm	23	/	3,3	2,2	1,5	?	P1	F4	H2/H3	/	/	/	?
Timmendorf-Nordmole III (G, -4500/-4100)	Fragment	Ash	26	/	4,6	1,4	3,3	?	P1	F4	?	?	S2b	?	?
Agernaes (Dk, -4300/-4100)	Complete	Elm	/	111-117	?	?	?	?	P1	F4	?	?	?	?	?
Rosenhof LA58/1 (Nor, -4050/-3150)	Fragment	Elm	88	135	3,3	1,7	1,9	2,4%	P1	F4	?	?	S1g	?	?
Rosenhof LA58/2 (Nor, -4050/-3150)	Fragment	Elm	74	160	3,1	1,9	1,6	1,9%	P1	F4	?	?	S1g	?	?
Rosenhof LA58/3 (Nor, -4050/-3150)	Fragment	Elm	?	/	1,8	2	0,9	?	P1	F4	?	?	?	?	?
Forstermoor Satrup (G, -3000/-2750)	Fragment	Elm	106	115	2,7	1,8	1,5	2,3%	P1	F4	H2/H3	S5e	S1d	S1d	?
Muldbjerg (Dk, -2900/-2740)	Fragment	Elm	151	155-160	3,7	1,5	2,5	2,5%	P1	F4	H2/H3	S1a	S1g	S1g	Mostly

Fig. 9. Map of propeller Ertebolle bows.



Right Fig. 10. Ringkloster + Immendrof drawings (credit : Andersen S., H.: Tybrind Vig. Submerged Mesolithic settlements in Denmark. Højbjerg 2013, 145-146).

The 'Ertebolle' appendiculate bow

Appendiculate bows appeared at approximately the same time as propeller bows, and in the same region. At first glance, you might think this is an evolution of the propeller bow, an attempt to make this wide bow more aerodynamic. Indeed, refining the last third of the bow limbs with less width and a little more thickness to avoid breakage, gives less air resistance, less inertia and a higher speed of arrow. Maybe this was the intention but they did not supplant propeller bows. On the contrary, we find both types of bows in the same Ertebolles settlements.

The first and best known is Mollegabet's 115cm Elm Bow (5400BC), but it is not the only one. These elm bows have also been found in Tybrind Vig (types 1 and 3, 11 bows, 5300 / 4000BC), Ringkloster (4800/4550BC), Timmendorf Nordmole II/2 (5100/4500 North Germany), and Maglemosegaard (4300/4100). We can add the bow of Horsens Fjord (4700BC) which is made of ash.

Although rarer than propeller bows, these bows are nonetheless numerous enough to prove that this was indeed a distinct family of bows, and not occasional trials. However, these bows did not diffuse outside the Ertebolle zone of influence and they disappeared with it.

Table 3 "Ertebolle" appendiculate bows

Bow (Location, date)	Info	wood	Real length	Estimated length	width	depth	Fs	Fw	Profile	Face	Handle	handle section	limbs section	End of limbs section	Outer ring preserved
Mollegabet (Dk, -5400)	Fragment	Elm	115	/	3,6	1,5	2,4	3,1%	P1	F6	H2/H3	S5e	S1g	S3b	Yes
Tybrind Vig - t1 (Dk, -5300/-4000)	Fragment	Elm	?	150-160	3	1,5	2,0	2-2,5%	P1	F6	H2/H3	S5e	S1g	S1a	Yes
Tybrind Vig - t1 (Dk, -5300/-4000)	Fragment	Elm	?	150-160	3,1	1,6	1,9	2-2,5%	P1	F6	H2/H3	S5e	S1g	S1a	Yes
Tybrind Vig - t1 (Dk, -5300/-4000)	Fragment	Elm	?	150-160	3,2	1,7	1,9	2-2,5%	P1	F6	H2/H3	S5e	S1g	S1a	Yes
Tybrind Vig - t1 (Dk, -5300/-4000)	Fragment	Elm	?	150-160	3,3	1,8	1,8	2-2,5%	P1	F6	H2/H3	S5e	S1g	S1a	Yes
Tybrind Vig - t1 (Dk, -5300/-4000)	Fragment	Elm	?	150-160	3,4	1,9	1,8	2-2,5%	P1	F6	H2/H3	S5e	S1g	S1a	Yes
Tybrind Vig - t1 (Dk, -5300/-4000)	Fragment	Elm	?	150-160	3,5	2	1,8	2-2,5%	P1	F6	H2/H3	S5e	S1g	S1a	Yes
Tybrind Vig - t1 (Dk, -5300/-4000)	Fragment	Elm	?	150-160	3,6	2,1	1,7	2-2,5%	P1	F6	H2/H3	S5e	S1g	S1a	Yes
Tybrind Vig - t1 (Dk, -5300/-4000)	Fragment	Elm	?	150-160	3,7	2,2	1,7	2-2,5%	P1	F6	H2/H3	S5e	S1g	S1a	Yes
Tybrind Vig - t1 (Dk, -5300/-4000)	Fragment	Elm	?	150-160	3,8	2,3	1,7	2-2,5%	P1	F6	H2/H3	S5e	S1g	S1a	Yes
Tybrind Vig - t1 (Dk, -5300/-4000)	Fragment	Elm	?	150-160	3,8	2,3	1,7	2-2,5%	P1	F6	H2/H3	S5e	S1g	S1a	Yes
Tybrind Vig - t3 (Dk, -5300/-4000)	Fragment	Elm	17,6	/	2,5	1,4	1,8	/	P1	F6	H2/H3	S5e	S1g	?	Yes
Ringkloster 2 (Dk, -4790/-4540)	Fragment	Elm	106	174	/	/	/	/	P1	F6	H2/H3	?	?	S1a	?
Timmendorf-Nordmole II/2 (G, -5100/-4500)	Fragment	Elm	?	100	5	2,5	2,0	5,0%	P1	F6	/	/	S1g	S2e	Yes
Maglemosegard 1 (Dk, -4300/-4100)	Fragment	Elm	128	194	3,9	2,1	1,9	2,0%	P1	F6	H2/H3	S5e	S2a	S1a	Yes
Maglemosegard 2 (Dk, -4300/-4100)	Fragment	Elm	85	185	3,5	1,5	2,3	1,9%	P1	F6	H2/H3	S5e	S1g	S1a	?
Maglemosegard 3 (Dk, -4300/-4100)	Fragment	Elm	140	155	3	2,5	1,2	1,9%	P1	F6	H2/H3	/	/	/	?
Horsens Fjord (Dk, -4700)	Fragment	Ash	135	166	5,5	/	/	3,3%	P1	F6	H2/H3	S2e	S1g	S1g	?

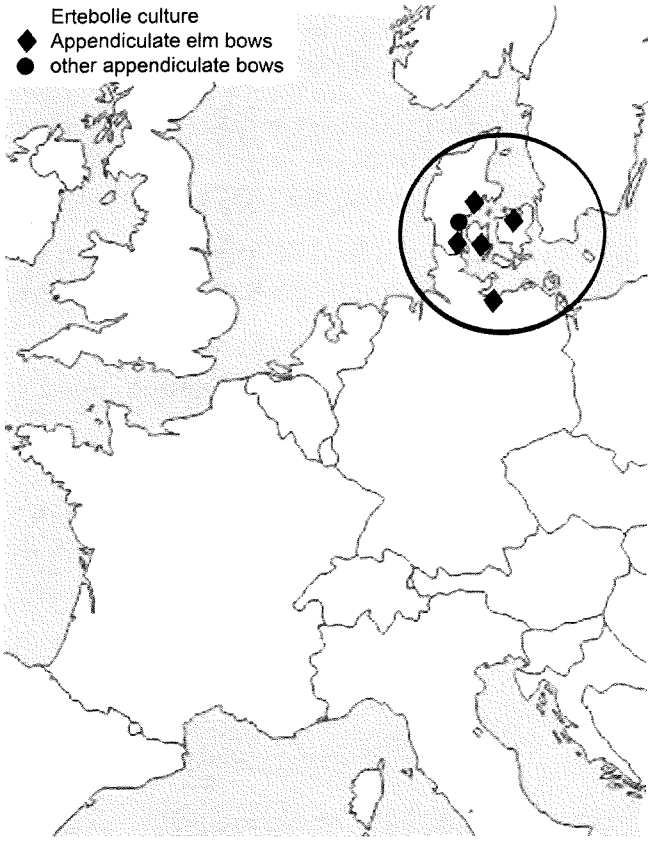


Fig. 11. Map of appendiculate Ertebolle bows.

Fig. 12. Tybrind Vig type 1 bow drawing. (source Andersen S. H. 2013).

'Late European' propeller bows

This southerly diffusion begins quite early then around 5100/4900BC we find an elm bow in Kuckhoven (western Germany) and a yew bow in Hardinxverld (Holland). This is barely 400 years after the Mollegabet bows. We will notice here one of the first yew bows found in Europe (although not the first, as we will see later), and probably an attempt to mix the yew wood, used for the thinner section of southern European bows, and the "Ertebolle" bows with a wide section. We then have to wait until the end of the Ertebolle culture (4000BC) to have other examples of this bow, elsewhere in Europe. It will be prevalent in three distinct areas: the British Isles, Holland, and Switzerland. With two exceptions, all of these bows will be of yew.

We first have the Rotten Bottom bow (4040/3540BC, England), then a series of propeller bows appear in Switzerland (and nearby regions) on the sites of the lake settlements which have given us many neolithic yew bows (smaller and more 'classical' section therefore). These are the bows of Bodman (4000/3000, Germany), Zurich Seefeld 1 (3179/3158BC), Horgen Scheller (3100BC), Zurich MozartStrasse (3126/3058BC), Chalain 1836 (4000 / 2000BC, France), Robenhausen (2800/2500).

The Meare Heath bow (2810/2570BC) in England is also part of this propeller series, but it should be noted that this one has bindings on the limbs, which the other bows do not.

We find again some bows in Holland and nearby Germany, almost 2000 years after the bows of Kuckhoven and Hardinxverld. These are the bows of Vrees (3000/2500, Germany), Ochsenmoor (two arcs, 2500 /2300BC, Germany), De Zilk (2000 / 1700BC, Holland). The series of propeller bows will end with the bows of Ledro and Fiavré Carera (1600 /1400BC, Italy). Note that Fiavré gives us a cornel bow. From that moment on, prehistoric wide bows will disappear from Europe, giving way to Neolithic yew bows, with which they coexisted for a long time. The next bows that will be found in Denmark will be the yew bows, the same style as bows in the rest of Europe, at the end of the Roman period, at Vimose and Nydam.

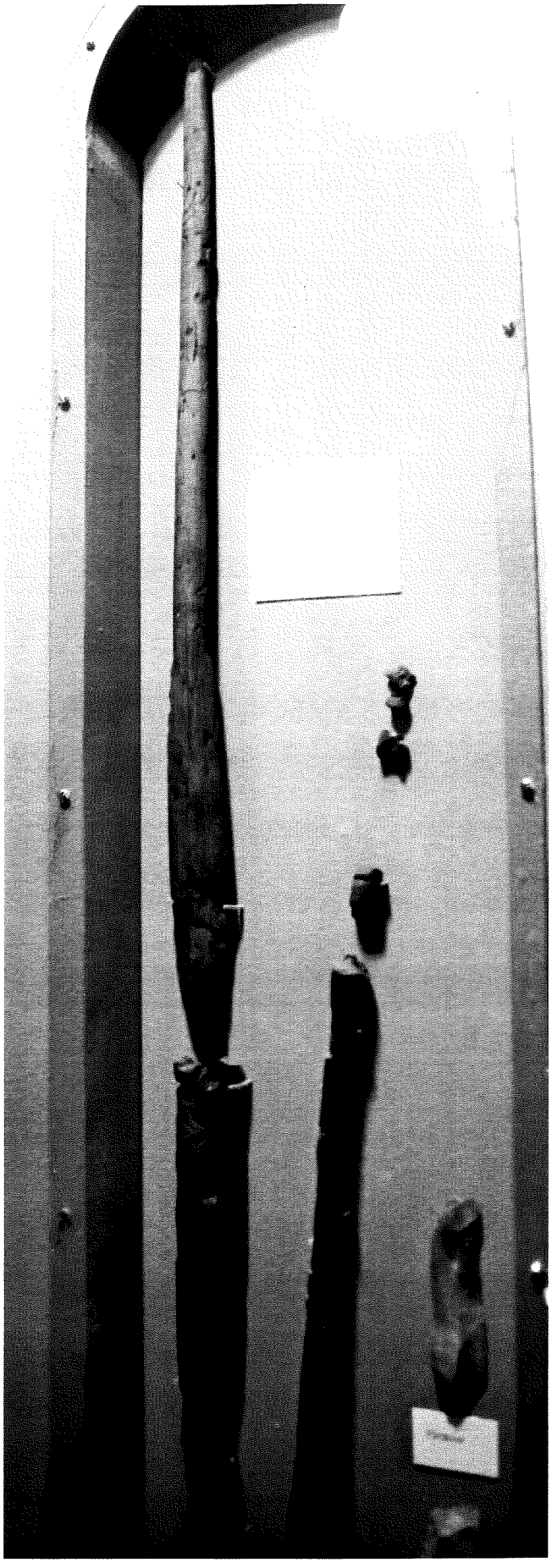


Fig. 13. Picture of Maglemosegaard bows. Vedbaekfundene Museum, Holte, Denmark (photo B. Detienne).

Table 4 "Late european" propeller bows

Bow (Location, date)	Info	wood	Real length	Estimated length	width	depth	Fs	Fw	Profile	Face	Handle	handle section	limbs section	End of limbs section	Outer ring preserved
Kückhoven-Erkelenz LBK (G, -5090)	Complete	Elm	?	120-140	?	?	?	?	P1	F4	H2/H3	?	S2a	?	?
Hardinxverld Giessendam (Hol, -4900)	Fragment	Yew	100	170	5	2,2	2,3	2,9%	P1	F4	H2/H3	?	?	?	?
Rotten Bottom (UK, -4040/-3540)	Complete	Yew	136	174	?	?	?	?	P1	F4	H2/H3	S2e	S1g	S3e	?
Bodman (G, -4000/-3000)	Complete	Yew	153	/	3,7	?	?	2,4%	P1	F4	H2/H3	S2e	S1e/S36B	S1e/ S36B	?
Chalain 1836 (F, -4000/-2000)	Fragment	Yew	117	167	3,37	?	?	2,0%	P1	F4	H2/H3	?	?	?	?
Zurich Seefeld 1 (S, -3179/-3158)	Complete	Yew	100	/	3,7	?	?	3,7%	P1	F4	H2	S5f	S2a	S2a	?
Horgen Scheller (S, -3050/-3032)	Fragment	Yew	130	/	?	?	?	?	P1	F4	H2/H3	S2e	S1f	S1f	?
Zurich Mozartstrasse (S, -3126/-3058)	Complete	Yew	?	80-100	?	?	?	?	P1	F4	H2/H3	S2e	S1g	S1g	?
Robenhausen 2 (S, -2800/-2500)	Complete	Yew	164	/	2,9	2,1	1,4	1,8%	P1	F4	H2/H3	S2e	S1f	S3e	?
Meare Heath (UK, -2810/-2570)	Fragment	Yew	93	190	6,85	1,75	3,9	3,6%	P1	F4	H2/H3	S2e	S1g	S1g	?
Vrees (G, -3000/-2000)	Complete	Yew	172	/	5			2,9%	P1	F4	H2/H3	?	?	?	?
Ochsenmoor / Diepholz (G, -2500/-2300)	Fragment	Yew	113	126	3,3	1,65	2,0	2,6%	P1	F4	H2/H3	S2e	S1g	S1g	?
Ochsenmoor / Diepholz (G, -2500/-2300)	Complete	Yew	146	/	3			2,1%	P1	F4	H2/H3	S2e	S1g	S1g	?
De Zilk (Hol, -2000/-1700)	Fragment	Yew	150	160	5,2	1,85	2,8	3,3%	P1	F4	H2/H3	S5g	S1g	S1g	?
Ledro A (It, -1600/-1400)	Fragment	Yew	90	144	?	?	?	?	P2 ?	F4	H2/H3	S2e	S2a	S2a	?
Ledro B (It, -1600/-1400)	Fragment	Yew	?	/	?	?	?	?	P1	F4	H2/H3	S2e	S2a	S2a	?
Fiavé Carrera I.63 (It, -1600/-1400)	Fragment	Mountain ash	133,2	145,6	?	?	?	?	P1	F4	H2/H3	S2e	S1g	S1g	Yes

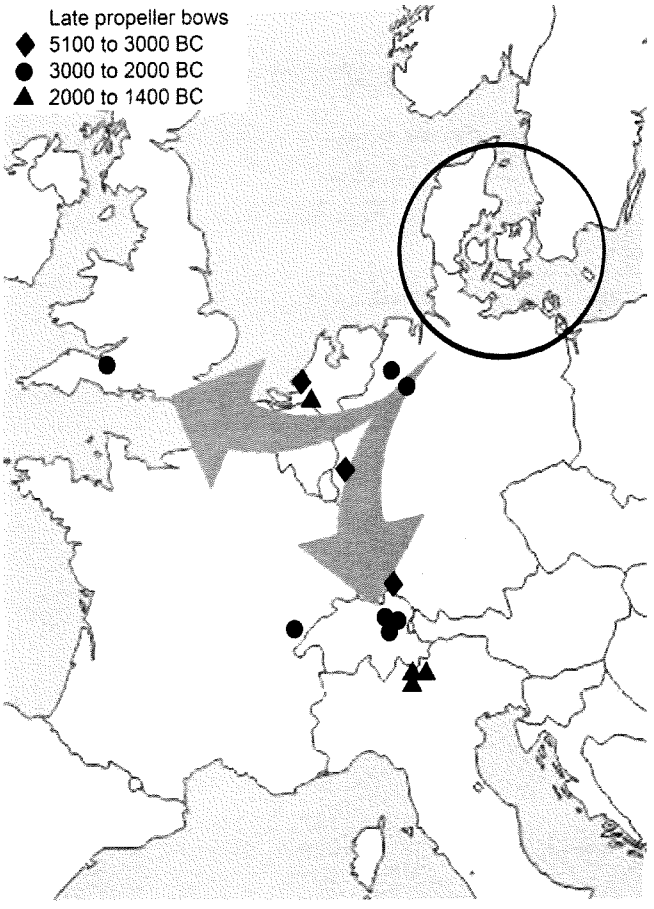


Fig.14. Map of late propeller bows.

Length of the prehistoric wide bows

The length of a bow is an important measurement. It is often considered in comparison to the size of the archer who uses it, which does not make things easy for historical interpretation. A bow has rarely been found with its archer next to it, although some cases exist such as Otzi (the 'Ice man'), in the alps. Care should be taken in comparing sizes, because while height is often proportional to the archer's draw, shooting at full draw has not necessarily been the norm since the dawn of time. Quite the contrary in fact if we look at the current way of shooting with a bow, by so-called 'primitive' tribes, we will realise that the shooting technique is absolutely not 'at full draw'. Also the average height of humans has tended to increase over the centuries.

However, comparing the sizes can give a general idea of the use of bows. We can therefore consider that a bow longer than the average human size (1.65 m to 1.75 m) will be called a 'long bow', and that a smaller bow (less than 1.60m) will be a 'small bow' or a bow for child or teenager.

Unfortunately, few have reached us complete (and even less 'intact'). But some can be estimated with a reasonable margin of error (such as the Meare Heath bow of which a 'full' half has been found).

We may notice that the pyramidal bows are quite long. They measure between 155 cm and 175 cm long, the majority being estimated around 160 cm, either equivalent or just below human size. For propeller bows, the Mollegabet cornel (dogwood) bow is complete, but measuring 86 cm it can only be a children's bow. The actual length of the three full Ertebolles propeller bows we have ranges from 154 cm to 170 cm. The estimated lengths of the interpretable fragments have sizes similar to, or just smaller than, human sizes, taking into account errors of extrapolation, and variations in human size from one individual to another. The appendiculate bows are more complicated to analyse since they are all fragments. Nevertheless, the bows of Maglemosegaard (for example) are majority fragments and little material is missing. The extrapolations lead us here also to lengths, oscillating between 150 and 190cm, equivalent or just under a human size.

As for the late propeller bows, during thediffusion in Europe and the adaptation of this model to the yew, we often find lengths (actual or estimated) of the order of 100 cm to 150 cm. Yet the Vrees bow is 172 cm and Meare Heath's bow was supposed to be 190 cm. There is therefore a much greater variation in length here. This variation in length corresponds to the great variability in the lengths of yew bows generally during the Neolithic period, so there is nothing surprising here.

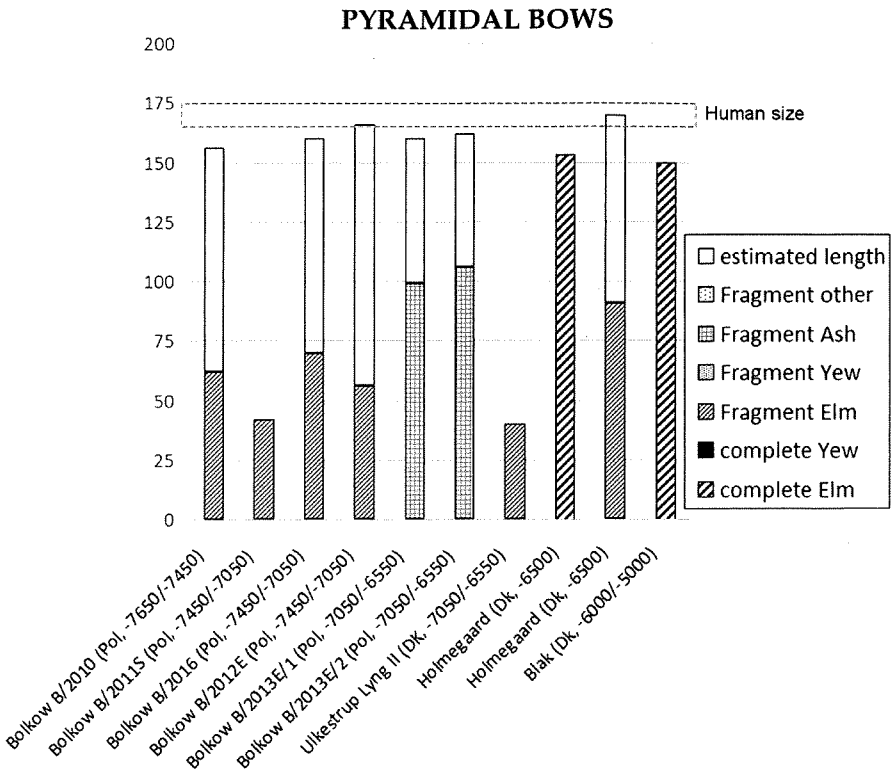


Fig. 15. Pyramidal bows lengths.

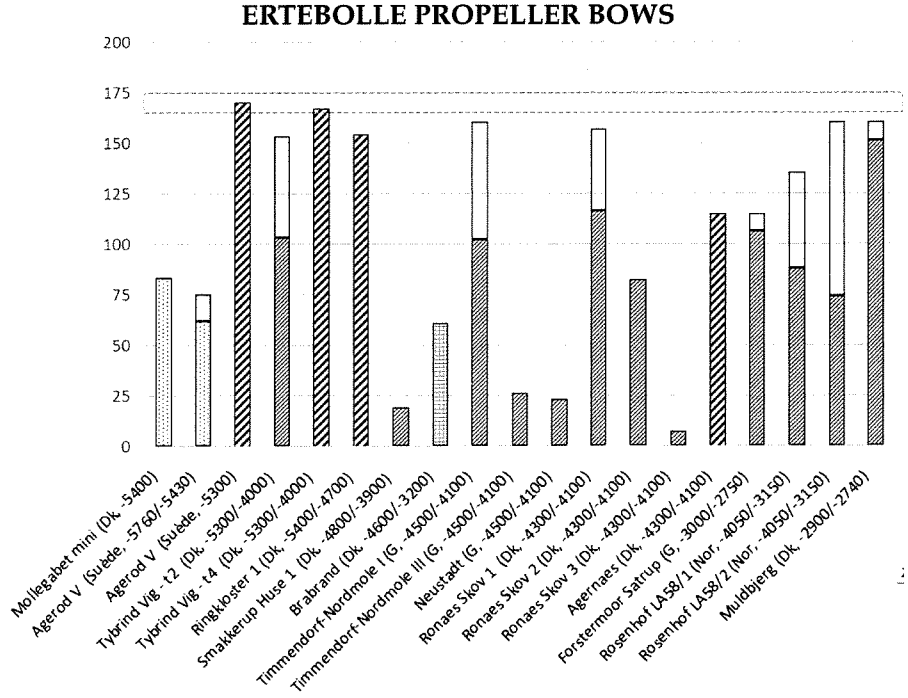


Fig. 16. Propeller ertebolle bows length.

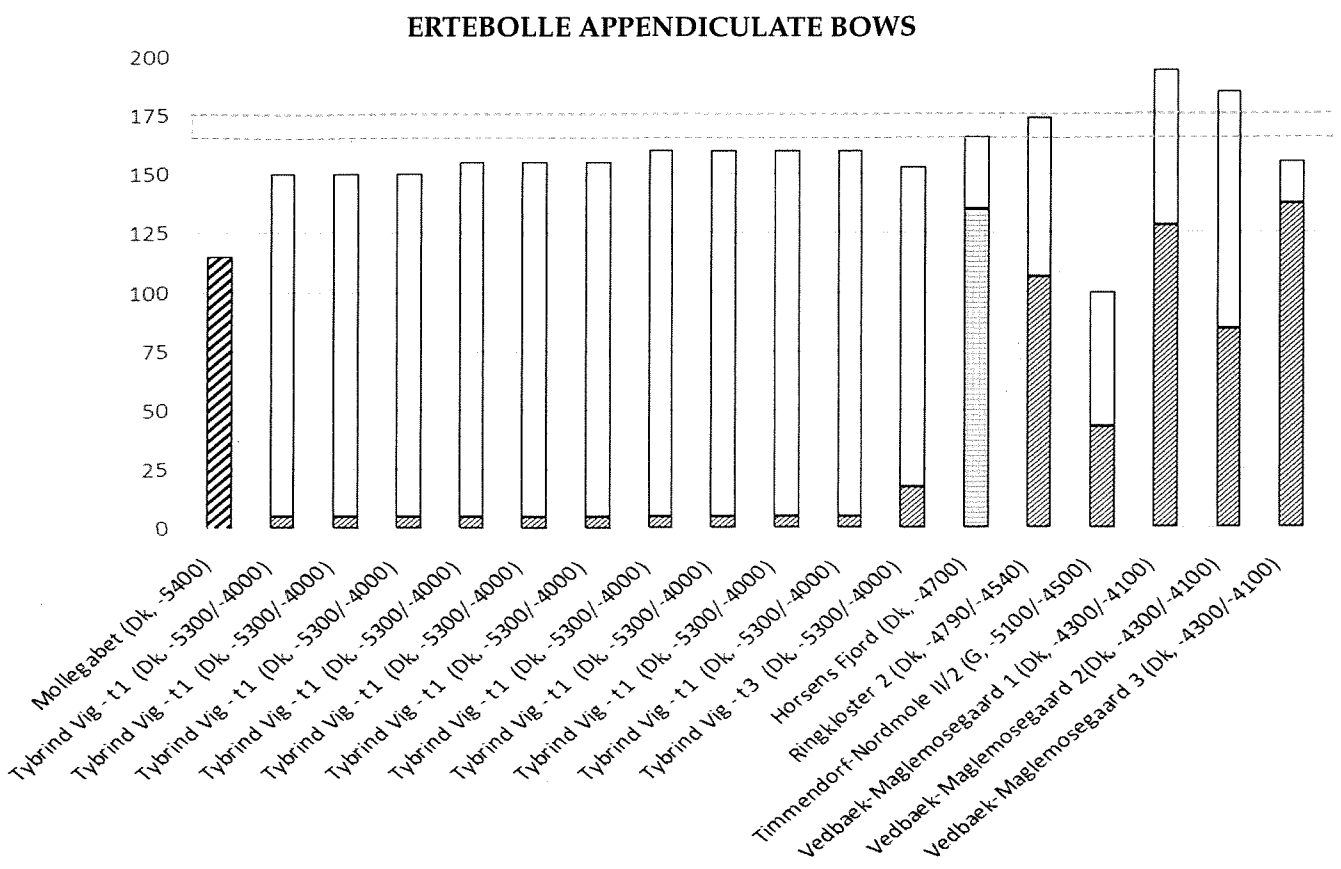


Fig. 17. Appendiculate ertebolle bows length.

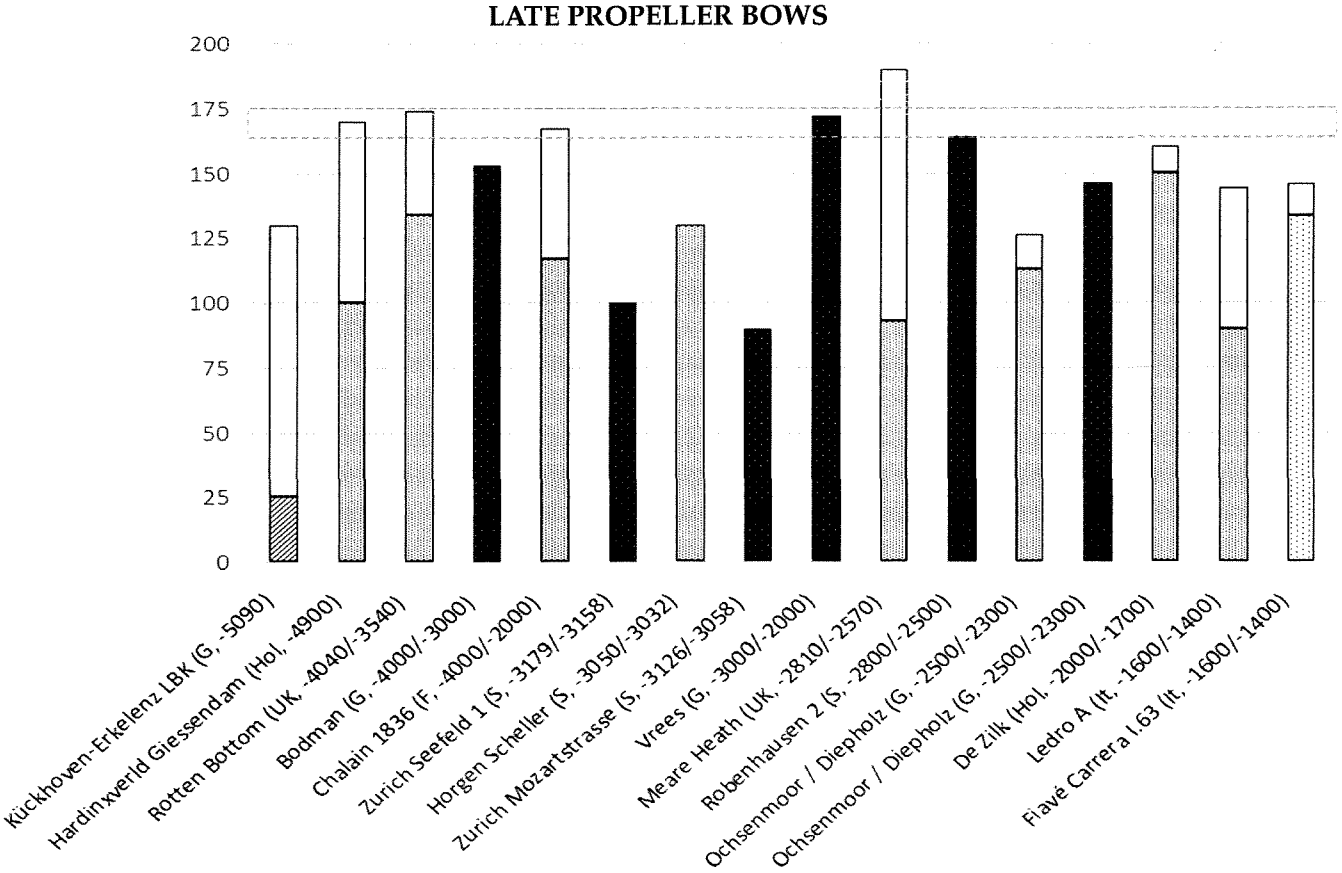


Fig. 18. Late propeller European bows length (note that for the Tybrind Vig bows, I dont have the real length but only the estimated length).

Early yew bows

Of course, the appearance of yew bows dates neither from the Roman period (200/400AD, Vimose), nor from the propeller bows of Hardinxveld (4900BC). They appeared long before, with the arrival of yew in southern Europe. The purpose of this article is not to detail these bows, but I will just cite a few key elements here.

We will first notice the three bows of Banyoles (5400 / 5200BC, Lake La Draga, Spain), the only ones that have been found in Spain to date. Then the yew forests go north, and we find a bow at Paris-Bercy (4400BC) at about the same time as the enormous number of bows in the Swiss lake settlements (distributed from 4000 to 2500BC). The yew will continue to conquer Europe bringing these bows to Germany and Great Britain, continuing the history of bows in Western Europe until the Hundred Years War, the bows of the Mary-Rose, and until nowadays.

Bow tips evolution

For the analysis of the characteristics of bows to be complete, it remains to address one more subject: the way in which the bows are prepared to receive the string. The ends of bows can in fact be worked in a number of different ways; the best known of which are the grooves we call nocks (notches) cut into the stave, and added horn nocks. But other systems have coexisted or succeeded each other over time. Of course, these stringing techniques do not define bow families, and are certainly not specific to prehistoric times, so this last section will go a little beyond the time limits of the rest of this study.

We can thus define some bow families, by the tips of bows. First, there are bows *without any arrangement (T1)* for the string, either for one limb of the bow or for both. We also find so-called *'ovoid' ends (T2)*, which choke slightly, either deliberately under the effect of sanding, or under the pressure of the knot of the rope over time; it is sometimes hard to distinguish between the two.

We also see the appearance, for a few thousand years, of *shoulders (T3)* worked at the ends of the bows limbs. We can define these as the clear interruption of the width of the limb, to obtain a pronounced constriction, then an end of the limb, either of this new width, or more or less wide, and of various shapes.

String *grooves (T4)* have not existed for as long as one might imagine, given their simplicity.

Table 5 Tips from prehistoric wide bows

Bows (Location, date)	Tip 1	Tip 2 (if exist)
Mannheim (G, -15.000)	(T2)	/
Holmegaard (Dk, -6500) *2pc	T1	T1
Mollegabet mini (Dk, -5400)	T3b	T1
Ringkloster 1 (Dk, -5400/-4700)	T1	T1
Banyoles (Sp, -5400/-5200) *3pc	T1, T3a, T3e	T3a
Tybrind Vig (Dk, -5300/-4000) *12pc	T1, T3a, T3e	T3b
Timmendorf-Nordmole II/2 (G, -5100/-4500)	T1	/
Grube-Rosenhof (G, -5100/-4500)	T1	/
Ringkloster 2 (Dk, -4790/-4540)	T1	/
Horsens Fjord (Dk, -4700)	T1	/
Smakkerup Huse 1 (Dk, -4800/-3900)	T1	/
Brabrand (Dk, -4600/-3200)	T1	/
Maglemosegard 1 (Dk, -4300/-4100)	T4c	/
Ronaes Skov (Dk, -4300/-4100)	T3a	/
Forstermoor Satrup (G, -3000/-2750)	T1	/
Rotten Bottom (UK, -4040/-3540)	T1	/
Bodman (G, -4000/-3000)	T1	T1
Zurich Seefeld 1 (S, -3179/-3158) *4pc	T1, T3c	T3a, T3c
Horgen Scheller (S, -3100)	T1	/
Zurich Mozartstrasse (S, -3126/-3058) *4pc	T1, T3a	T1, T3b
Muldbjerg (Dk, -2900/-2740)	T3a	/
Meare Heath (UK, -2810/-2570)	T3a	/
Robenhausen 2 (S, -2800/-2500)	T3b	T3b
Ashcott Heath (UK, -2665)	T3b	/
Ochsenmoor / Diepholz (G, -2500/-2300) *2pc	T3a	/
Ledro (It, -1600/-1400) * 5pc	T1, T2, T4a	T1
Fiavé Carrera I.63 (It, -1600/-1400)	T1	/

Some bows show *perforations (T5)*, rarely alone, usually coupled with a groove. And of course, *added horn nocks (T6)*, in animal horn or in deer antler (bone), appeared at the end of the Middle Ages.

Of course, it is obvious that the same bow, having two limbs and therefore two string locations, can have ends of two different families, or two ends of the same family. Although this analysis is only valid for the bows whose state of preservation of the ends is sufficient to allow this anaylsis, one can generelly draw some conclusions from the currently possible observations.

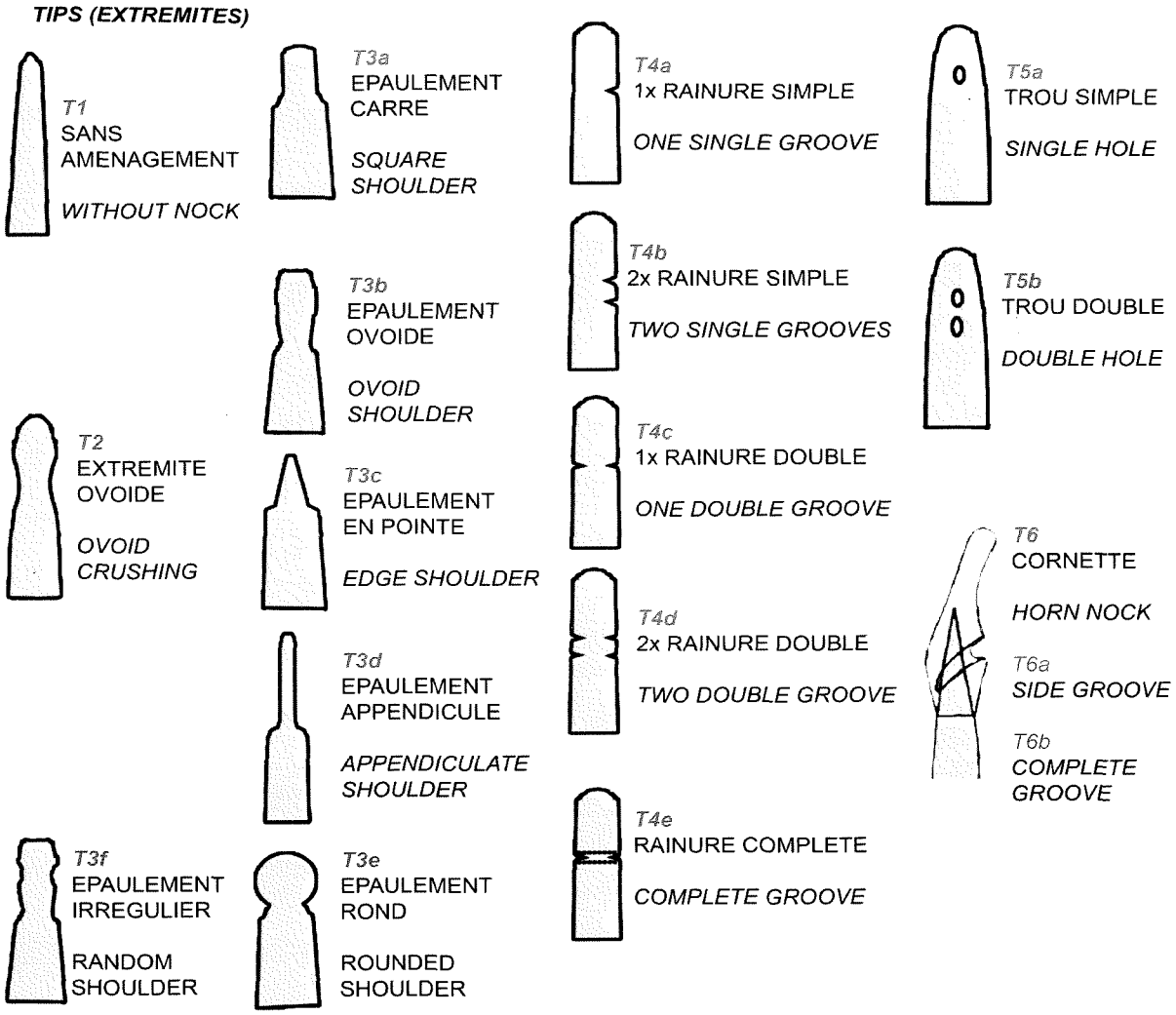


Fig. 19. Bow tips families.

Regarding the large prehistoric bows, we will mainly find bows without any development of the ends. The strings must therefore be tied at the ends of the two limbs, which implies making a knot at one of the two limbs while the bow is under tension. We will also begin to see that bows appear with shoulders of various shapes. The shoulders indeed appear from the beginning of the Neolithic period. They coexist with bows without modification and will remain in use until the Metal Age, regardless of the type of bow, wide or not. Ovoid ends do exist but remain quite rare, being mainly found on yew bows, at the end of the Neolithic period and at the beginning of the Bell Beaker period.

Grooves and perforations will not really appear until the middle of the Metal Age, with a few notable exceptions. They will replace the shoulders and will be used until the end of the Middle Ages. As for the horn nocks, they will not diffuse across Western Europe until the 15th century, probably from Germany. But this is outside the scope of this study and will therefore need to be the subject of a more specific study, covering a wider period.

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